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A performance comparison of oversewn, PVA double fanned, and cleat-laced bindings

Caroline Frazer Watson

A PERFORMANCE COMPARISON OF
OVERSEWN, PVA DOUBLE FANNED, AND CLEAT-LACED BINDINGS

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing in the College of Graphic Arts and Photography of the Rochester Institute of Technology

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Certificate of Approval--Master's Thesis

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Librarians and library binders are no longer always able to specify the traditional, superior oversewing method for binding library books. This problem emerged due to economic pressures within several related industries resulting in a proliferation of economic, but often inferior, binding technologies. As libraries are only approximately ten to fifteen percent of total publishers' sales, books cannot specifically be made for the library market. In addition, many of the new binding technologies yield books with insufficient inner margin space to prebind or rebind books utilizing the oversewing binding method. And finally, librarians, also faced with tight budgets, must find economic ways to bind library books.

This study concentrated on investigating and determining the merits of two alternate binding methods--PVA double fanning and cleat-lacing--and quantitatively comparing them with oversewing. The binding performance comparison tests were for both openability and strength (internal) properties, two main concerns for the rigors of library use. It was hypothesized that 1) all three binding methods would yield different openability and binding

strengths as the methods of fastening pages together work on different principles, 2) the strengths would be significantly influenced by two more main factors, paper and condition, and 3) the interactions of these three main factors (binding method, paper, condition) could significantly vary binding strength. Three different papers were tested: uncoated, dull, and glossy. The three conditions were new, used, and aged. Twenty-seven combinations of books were bound according to Class A, LBI Standard, specifications (except method of affixing pages) for testing.

A new precise method of measuring openability was devised for this study called "Openability Photocopy Test." The results, in general, proved that the PVA double fanned books opened better than both the cleat-laced and oversewn books, across all papers tested. The cleat-laced books opened slightly better than the oversewn volumes. Both oversewn and cleat-laced books were more consistent for openability than the PVA double fanned, across all papers.

The Martini Page Pull and Flex Tester was used to determine binding strengths by recording the force necessary (pounds per linear inch) to pull single pages out of a binding. The strength test results were analyzed by the statistical method called "analysis of variance." It was found that the critical (statistically significant) factors were the two main factors of binding method and paper but not condition. And it was further determined that the two-way interactions of paper/binding method, paper/condition, and binding method/condition also all vary the binding strengths significantly. The three-way multiple interaction effect, paper/binding method/condition, was not significant.

All book combinations tested yielded binding strengths which exceeded 4.0 lbs/in, a rating of "Excellent" by the Library Binding Institute. However, there was great variability above this level (a range of 4.26 to 8.50 lbs/in). In general, the PVA double fanned bindings had the greatest strengths, oversewn second best, and cleat-laced books had the lowest scores. Uncoated paper yielded books with the greatest strengths, dull paper second, and glossy paper gave the least binding strengths. Particular combinations of paper, binding method, and condition (two-way interactions) caused variations in binding strengths so the general conclusions did not always hold true.

The results of the openability and strength tests were graphed and categorized in data tables. These graphs and tables can be used as an Optimum Binding Method Index for openability and strength for books of the dimensions and qualities set forth in this study. Librarians and library binders may now make more informed decisions in selecting a proper alternate binding method for a book, cleat-lacing or PVA double fanning.

CHAPTER 1

INTRODUCTION

The purpose of this study is to determine the comparative merits of three different binding methods. This study is necessary because librarians and library binders today are faced with more decisions than in the past as to what are the most suitable binding techniques for prebinding or rebinding library books, books which normally get a lot more use or "wear-and-tear" in the library than they would anywhere else. The three binding methods, oversewing, PVA double fanning, and Smyth cleat-lacing, were tested and compared to determine their relative openability and internal strength performances.

The binding industry is not the same industry of a few years ago. Many changes have been taking place resulting in a myriad of new binding methods, materials, and technologies particularly in adhesive binding techniques. "Where sewn bindings dominated the 1960's, adhesive bound books are increasing and now amount to over 50% [1976, 80-90% in 1983] of all casebound books being produced at major book manufacturers."[1] The new technologies offer advantages to competitive binders and publishers while the buyer of books, still paying a high price for these often inferior casebound books, suffers. Werner Rebsamen, Technical Consultant to the Library Binding Institute and Professor at Rochester Institute of Technology, states, "Despite tremendous technical advances in adhesive binding techniques, there is a serious deterioration in good case-binding. The buyer of books, paying a steep $9-14 [1977] for a hardcover volume, is no longer guaranteed that the binding will last much longer than that found on a regular paperback book."[2] This situation has created special problems and disadvantages for librarians and the library binding industry.

The library binding industry is a unique branch of the binding industry. Its main function is to bind books in such a way as to prolong their useful life. In the past the vast majority of library books were bound by a specific type of binding, "library" or "Class A," developed for the rigid requirements of library use. Volumes were thus bound according to high standards and specifications known to yield strong and durable books. "That meant that both the buyer and the seller had a clear understanding of the product being bought and sold."[3]

Due to economic pressures within several related industries and the proliferation of new technologies with resultant physical changes in books, librarians and library binders are forced to consider methods other than the traditional Class A binding which specifies the oversewing binding method. This is not an easy task as there is a lack of valid data and information on just how well alternate binding methods perform, in terms of strength and durability, in comparison with Class A oversewing. There is no longer the clear understanding between buyer and seller of the product being bought and sold. Unless new technologies are adequately tested, which they have not been, sound decisions as to which alternate methods may be sufficient or possibly preferable for library use cannot be made.

An explanation of library binding requirements and Library Binding Institute's Standard (Class A) is presented in the following two sections to focus on where the exact problems lie in finding suitable alternate binding methods and why PVA double fanning and Smyth cleat-lacing were promising candidates for testing.

Library Binding Requirements

To shed light on the special requirements of binding library books, Jack Bendror in his book, Technology and Testing of Library Bound Books, distinguishes the library binding industry as follows:

> The library binding industry is often characterized as being unique for several reasons, among which the following two are most important:

1. The library binder must work on a product someone else has made. Consequently, he has no control over variables, such as wear, weight, quality of paper, grain-print relationship, margin size, diversity of volume, and size, all of which are important in the rebinding process.

2. Hence, from a technological point of view, and because of the lack of homogeneity in the product, it is a separate and distinct branch of the graphic arts industry.[4]

Furthermore, some library materials are subjected to heavy usage, a large number of circulations. This may cause a great strain on bindings. Thus, the rebinding or prebinding must meet high strength requirements and standards. Rebinding is the process of replacing worn bindings where prebinding is the process of binding new books for library use. The library binding industry's task then has been to turn a non-uniform product into a uniform one in terms of strength and durability, of superior quality to the original edition binding.

Library Binding Institute's Standard

The Library Binding Institute serves both librarians and library binders in an effort to meet more effectively the above binding requirements. Approximately eighty percent of all libraries rely upon Certified Library Binders who observe the nationally-accepted "...Library Binding Institute (LBI) Standard for Library Binding (sometimes called Class "A") providing maximum strength and durability

(100-150 circulations or use)."[5] "By adhering to these standards inferior binding has largely disappeared from the library scene."[6] This latter statement was written in 1956 and inferior bindings have reappeared on the scene because it is no longer always feasible to adhere to the specifications (as explained further on in this chapter), and also because not enough is known about the strength or weaknesses of alternate binding methods.

LBI's specifications are for both materials and methods. The binding method specified (excluding exceptional volumes) is oversewing. Oversewing is a technique where individual sections of loose leaves are sewn through the side, then sewn to the next section(s) and so on. A lock stitch is formed between each separate section. Openability is better than a side-sewn volume as the stitches are not through the entire block at once. (For a more detailed explanation, see Chapter 2.)

LBI also encourages the development of new equipment and materials. "Its object is clear: to make available materials equivalent or superior in quality to specified materials, and equipment which can increase productivity per man hour with no diminution of quality."[7] The LBI Technology committee researches and tests new materials and methods for their performance in comparison with the Standard, thus providing technical data to binders and librarians.

Class A, the standard for binding 99 percent of all library books in the past,[8] specifies the still preferred method of oversewing for many reasons, among which are the following five important ones:

1. Oversewing gives great strength to a book.
2. An oversewn volume has reasonably good openability.
3. Oversewing can be performed in-line with other specified procedures of Class A binding.
4. Loose leaves may be bound, no bindfold necessary.
5. With equipment adjustments, a wide range of book types (physical characteristics) can be bound by the oversewing technique. Although more costly, odd sizes can be oversewn by hand, an accepted Class A technique which broadens the range even further.

These five attributes of oversewing are the primary ones which LBI, library binders, and librarians investigate when considering alternate binding methods.

Statement of the Problem

Many of the new technologies in binding not only offer automation of production lines but also present a second gain to the publishing industry by reducing the quantity of paper necessary to bind a volume. The inner margin space used after milling or trimming is negligible compared with oversewing. The scarcity of paper with its attendant high cost prompted publishers to take advantage of this minimum requirement by décreasing trim sizes and inner margin spaces. This is particularly troublesome for library binders in the rebinding or prebinding process.

Oversewing demands an inner margin space of 5/8 inch minimum, 1/4 inch actually used in the sewing while the remainder is needed for readability (openability). Fairly good openability (the degree to which a volume can open flat, unaided) is a must and one of the requirements for Class A.

So the first problem is that library binders may not be provided enough inner margin space to utilize oversewing. The obvious solution of persuading the publishing industry to furnish wider inner margins is a difficult undertaking which cannot be accomplished in the near future. Dudley A. Weiss, former Executive Director of LBI, states, "It is easy to blame the publishers but, by and large, because the library market is 10-15% of total publishers' sales, books cannot economically be made specifically for the library market, with the exception of a limited number of publishers whose market is definitely oriented toward libraries."[9] Even if it were possible, there is still the problem of rebinding the multitude of narrow inner margin books already produced. The second solution, although not ideal, is for library binders to use the alternate binding techniques themselves. The librarian must first determine the end use of a volume. Not all books are circulated in the same manner in a library, some used less than others, and still others have early obsolescence dates. Consequently, the strongest binding method is preferable but not always essential. A volume can be bound just sufficient for its particular use. Once the end use, physical parameters of the book, and funds available are assessed, a suitable binding technique may be selected. Thus, libraries could take advantage of "budget bindings."

The problem this study addressed was that none of the plausible alternate methods had been adequately tested for their performance in comparison with Class A oversewing. Librarians can decide what volumes do not need or could not use oversewing. But the librarians and library binders often have little valid information or conflicting reports about the qualities of new techniques with which to select a proper binding method. It is even plausible that some of the new techniques could have merits that would be preferable to oversewing for certain kinds of volumes even if the inner margin space was sufficient for oversewing. Jack Bendror states, "We feel that recent changes in product mix make it imperative that different methods be evaluated in terms of performance so that the binder can adopt the appropriate technology for the end use. Conceivably, an OBMI (Optimum Binding Method Index) will emerge which will enable the library binder to select the binding method which will meet requirements of the end use of a particular volume."[10]

Objectives and Hypotheses

The ideal long range objective is to provide a complete Optimum Binding Method Index and continue to update the OBMI as variations of binding methods and materials emerge. The aim of this study was to begin the OBMI and start at a point where the knowledge gained would be of immediate value and widely useful. Previous investigation had demonstrated two binding techniques, Smyth cleat-lacing and PVA double fanning, to be "at the top of the list" of alternate methods for satisfying library needs. Both binding methods have been gaining wide acceptance in the library binding industry for narrow inner margin and/or economic reasons.

Smyth cleat-lacing is a binding method that appeared on the market in 1970. It is a faster and more economical method than oversewing. Infringement of inner margin space is said to be 1/8 inch less than oversewing, and cleat-lacing can be performed with other specified procedures of Class A binding. It is a method where thread is "laced" in small sections around grooves cut across the width of a volume's spine and saturated with an adhesive application down its spine.

Double fanning with specially formulated high quality polyvinyl acetate (PVA) adhesives, or PVA double fanning, is the most durable adhesive binding technique. (For purposes of this paper at times this method will be referred to simply as double fanning.) A block of loose leaves is clamped while the spine is fanned in one direction for a glue application and fanned again in the opposite direction for a second application. Margin infringement, speed, and cost is less than either cleat-lacing or oversewing. (For a more detailed explanation of oversewing, cleat-lacing, and PVA double fanning, see Chapter 2.)

The main objective of this study was to compare directly and quantitatively PVA double fanning and cleat-lacing with Class A oversewing. The three binding methods (actual bound books) were tested for both the binding strength and openability performances, two of the five major concerns for the LBI Standard or Class A requirements. Openability performances were measured with a great degree of accuracy by a method devised for this study. However, the book preparations, testing design, and data analysis revolved principally around testing hypotheses about binding strength. How strong are the bindings and what factors have major influences on the results?

As the three binding methods in question work on three different principles (sewing, gluing, and lacing/gluing), the main hypothesis was that the binding strengths (internal strength, book block) are not the same or uniform, all other factors being equal (size, weight, paper, etc.). It was further hypothesized that the binding strengths would depend upon the paper used because paper previously has been demonstrated to affect binding strength within one type of binding method. Three papers were tested, all with 60 lb basis weight (see Chapter 4). The testing also was designed to find out if paper had as large an influence on strength as the binding method itself.

Two outcomes could possibly result from the binding/paper combinations. In the first hypothesized outcome, one binding method would outshine the other two, across all papers. And further, a second of the three methods would clearly have all the lowest scores, across all papers. Thus, each of the three binding methods would be in a strength category of its own even though paper influenced the strengths. The second outcome hypothesized to occur possibly was that the interactions of binding method and paper might cause one binding method to be best for one paper but least desirable for another paper. As librarians rarely have the choice of paper but do have the choice of binding method, this is essential to know. No matter which outcome became true, the strengths would be quantified (and repeatable), recorded, and librarians or binders would now know the relative strengths of each binding method/paper combination in standard units of measurement (pounds per linear inch), and thus a portion of an Optimum Binding Method Index completed.

A third factor was hypothesized to have a major influence on binding strength and incorporated in the experimental design of this study. This factor is called "condition" or "treatment." Books were tested for the condition of 1) new, 2) aged, and 3) used. New books or books just received from the manufacturer may or may not have more strength initially than after a period of time. Both paper strength and adhesive strength have been known to deteriorate over a period of time. Therefore, aging may show an appreciable difference in the strength. Also, books that are circulated a great deal (used) may lose binding strength due to "wear-and-tear." All three of these conditions (new, used, aged) were compared to determine their influences on binding strength as well as their interaction with both paper and binding method. And last, the degree of influence condition had on binding strength was compared with the degree to which the factors of binding method and paper influenced strength.

The above hypotheses were carefully tested and analyzed by graphs, and the statistical method called "analysis of variance" was employed for binding strength evaluations. In summary, the testing and analysis was designed to answer the following specific questions:

1. Are there differences in openability between the three binding methods?
2. If so, which volumes differ and exactly how much are the openability differences?
3. Are there significant strength differences between volumes tested?
4. If so, which volumes differ and how much are the strength differences?
5. Are the strength differences due to:
   a. binding method?
   b. paper?
   c. condition?
6. Are the strength differences due to two-way interactions between:
   a. paper/binding method?
   b. paper/condition?
   c. binding method/condition?
7. Is there a three-way, multiple interaction between binding method/paper/condition?

Other major factors such as grain-print relationship and size of volumes were purposely not included in this study. But it _is_ the intention of this study to begin an OBMI for these three binding methods and to lay the groundwork and direction for further investigations.

FOOTNOTES FOR CHAPTER 1

[1]Werner Rebsamen, "Testing Bindings--An Introduction," introduction to Jack Bendror, Technology and Testing of Library Bound Books (Rochester, New York: Graphic Arts Research Center, 1976), p. i.

[2]Werner Rebsamen, "Bookbinding Testing Laboratory Evaluates Machinery, Materials, Techniques," Book Production Industry & Magazine Production (May 1977), p. 63.

[3]Rebsamen, "Testing Bindings--An Introduction," p. i.

[4]Jack Bendror, Technology and Testing of Library Bound Books (Rochester, New York: Graphic Arts Research Center, 1976), p. 1.

[5]Ibid., p. 2.

[6]John B. Stratton, "Libraries and Commercial Binderies," Library Trends (January 1956), p. 308.

[7]Dudley A. Weiss, "The LBI Standard: The Only Industry Standard for Library Bound Books," The Library Scene (September 1975), p. 19.

[8]Rebsamen, "Testing Bindings--An Introduction," p. i.

[9]Dudley A. Weiss, "Book Deterioration--Who Is At Fault and What Can Be Done About It?," The Library Scene (June 1978), p. 9.

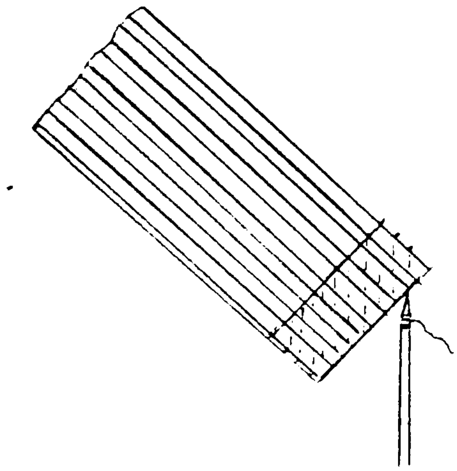
[10]Bendror, p. 25.

CHAPTER 2

DESCRIPTION OF THE OVERSEWING, PVA DOUBLE FANNING, AND CLEAT-LACING TECHNIQUES

Oversewing

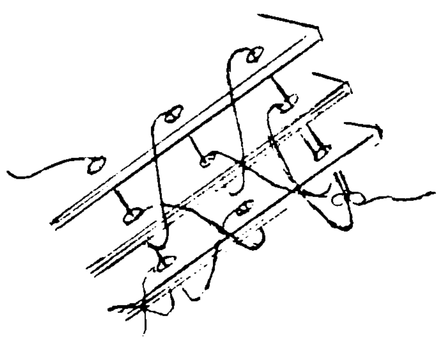
Oversewing is a binding technique which can be performed either by hand or by machine; the principle is the same for both. Oversewing by hand is sometimes used for unusual books (size, condition) which do not lend themselves to the oversewing machine. Machine oversewing requires extensive training for the operator as the pattern of sewing is quite complex. Pages of sections of folded signatures are prepared, or more often, a block of loose leaves is divided into separate but equal sections. The sections should be relatively small. "The oversewing machine has a series of individual needles which move diagonally through several sections at a time,"[1] through the edge of the sections. A lock stitch is formed with each separate section. Great strength is obtained because of the large number of stitches and because of the particular sewing pattern used. Flexibility is acquired since the sewing is not through the edge of the entire block of sections at once. Figure 1, The Over-Sewing Principle, and Figure 2, Oversewing Stitching Pattern, illustrate the oversewing binding method.



The oversewing principle incorporates a process in which the needles pass through the thread obliquely through thin sections, forming a lock stitch with each separate section.

(Drawing by Elizabeth Watson, original drawing and caption from: Werner Rebsamen, "Third Part in a Series On: A Study of Simple Binding Methods," The Library Scene, December 1979, p. 20.)

FIGURE 1. THE OVERSEWING PRINCIPLE



(Drawing by Elizabeth Watson based on diagram in: Victor Strauss, The Printing Industry, Washington, D.C.: Printing Industries of America, Inc., 1967, p. 659.)

FIGURE 2. OVERSEWING STITCHING PATTERN

PVA Double Fanning

The highest quality adhesive binding is achieved with an "internally plasticized" co-polymer PVA (polyvinyl acetate) cold emulsion adhesive with fanning, or PVA double fanning technique. Werner Rebsamen, in his article "Understanding Adhesive Binding Technology," describes the advantages of PVA as follows:

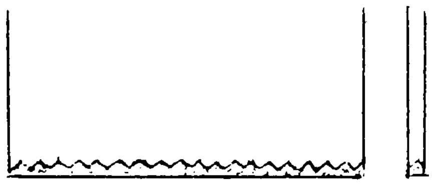
> Polyvinyl acetate (PVA) is a synthetic resin emulsion, usually white, which is applied cold. PVA has excellent thermoplastic and aging qualities, and best of all, is available acid-free. This adhesive is water-based: once applied to the spine of the book, the water evaporates and the solids polymerize into a thin, translucent film of great flexibility. PVA is the best material for adhesive binding, since the vehicle carries the resin deep into the structure of the stock, with consequent linking of paper fibers into the film. Drying must be slow, since polymerization takes time: a minimum of 2 hours must elapse if the bond and film structure are to be optimal.[2]

Rebsamen also describes the binding process:

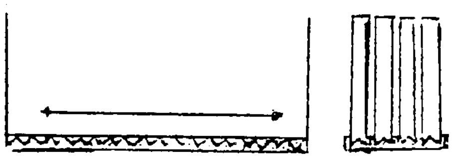
> The book pages are first bent one way, and a specially formulated high quality polyvinyl acetate adhesive is applied to the sides of every page; then the book is fanned in the opposite direction to receive a second application. ... Motorized double fanning machines prepare the backbone with a milling head. The book is then clamped a certain distance from its backbone and allowed to oscillate over a rotating glue roller so that pages are individually fanned in both directions. This process allows adhesive penetration between each page, thus "tipping" one page to another. The unusual strength of this binding is obtained with a straight, even glue line from head to tail, approximately 10 thousandths of an inch.[3]

Library binders have no control over some of the variables that influence the quality of adhesive bindings such as grain direction and paper quality. However, the degree of roughing or exposure of paper fibers is an important factor which should be considered, as illustrated in Figure 3, Double Fanning With Roughing.

A smooth, trimmed edge makes any penetration into the paper fibres difficult, making the adhesion not as effective.



The purpose of roughing or exposing more of the paper fibres is to increase the area exposed to the glue film, thereby improving the bonding power.



The combination of roughing and tipping one page to another results in the highest quality adhesive binding.

(Drawings by Elizabeth Watson, original drawings and captions from: Werner Rebsamen, "Fourth Part in a Series On: A Study of Simple Binding Methods," The Library Scene, March 1980, pp. 20, 21.)

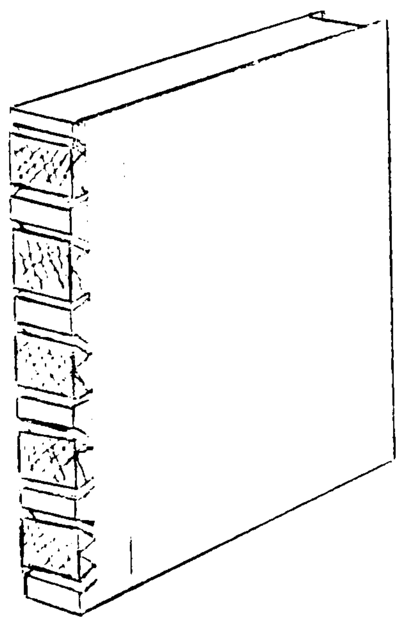
FIGURE 3. DOUBLE FANNING WITH ROUGHING

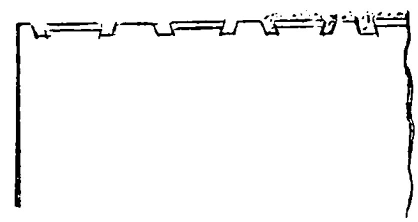
<u>Smyth Cleat-Lacing</u>

Cleat-lacing is a binding method that came on the market in 1970. The cleat-lacing machines were built by the Smyth Bookbinding Machinery Company. Werner Rebsamen describes the process as follows:

> For a new cleat-lacing binding method, as in oversewing, books to be rebound must have all old glue and sewing removed and the pages must be separated. Operating a cleat-lacing machine is simple and does not require the extensive training period as is the case with the oversewing machine. Parallel dovetail slits (cleats), approximately 1/8 inch wide and 1/8 inch deep are cut into the backbone at opposite angles. The machine determines the proper number of cleats throughout the height of the book being laced. After cutting the dovetail cleats, the books are automatically transported to the thread lacing station. A thread carrier then separates thin sections of the backbone to lace the pasted single thread through and around the cleats one at a time in a figure eight. This pattern is repeated over and over between the successive pair of dovetail cleats. No piercing of paper is required as in oversewing.
>
> The Smyth cleat-lacing machine is two to three times faster than the speed of a conventional oversewing machine. Unlike the oversewing machine, no adjustments are required on the cleat-lacer when changing from one book dimension to another. This results in a more economical binding which has wide acceptance in the library binding market. Lacing a single thread through dovetail cleats may sound technically complete. However, the final strength of a cleat-laced volume must come from a heavy coat of suitable adhesive. The cleats must be saturated preferably with a high-quality polyvinyl acetate (P.V.A.) especially if the volume is to be rounded and backed.[4]

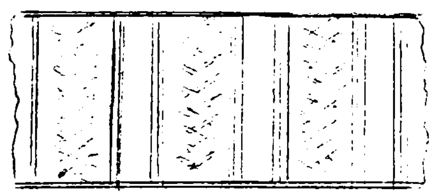
Ellen McCrady in her article "Preserving Inner Margins in the Library Bindery" points out that cleat-lacing saves about 25 percent more of the margin space left over after cutting than does oversewing. The process uses 1/8 inch out of 1/2 inch and since cleat-lacing opens more easily for reading even more space is saved.[5] Figure 4 below, Cleat-Lacing, illustrates the cleat-lacing method principle.





In the cleat-lacing principle, the cleat must be saturated since the final strength must come from a heavy coat of adhesive, preferably a high quality of polyvinyl acetate.

In this cleat-laced volume, the sawcuts are slightly enlarged for illustrative purposes.



This is a close-up view of a cleat-laced volume.

(Drawings by Elizabeth Watson, original drawings and captions from: Werner Rebsamen, "Third Part in a Series On: A Study of Simple Binding Methods," The Library Scene, December 1979, p. 21. Drawings by Barbara Rebsamen.)

FIGURE 4. CLEAT-LACING

FOOTNOTES FOR CHAPTER 2

[1]Victor Strauss, _The Printing Industry_ (Washington, D.C.: Printing Industries of America, Inc., 1967), p. 659.

[2]Werner Rebsamen, "Understanding Adhesive Binding Technology," _The Library Scene_ (March 1978), p. 13.

[3]_Ibid_., p. 16.

[4]Werner Rebsamen, "Third Part in a Series On: A Study of Simple Binding Methods," _The Library Scene_ (December 1979), p. 21.

[5]Ellen McCrady, "Preserving Inner Margins in the Library Bindery," _The Abbey Newsletter_ (September 1979), p. 32.

CHAPTER 3

LITERATURE REVIEW

The former Executive Director of the Library Binding Institute, Dudley A. Weiss, published several articles in the Institute's periodical, Library Scene. These include: "Book Deterioration--Who Is At Fault And What Can Be Done About It," "Library Binding--the State of the Industry," "The LBI Standard: The Only Industry Standard for Library Bound Books," "The Library Binding Institute: A Mini Profile," and "Revival of Attention to Binding Standards." Collectively these articles explain the function of LBI and its great value to librarians and library binders, whom it serves. LBI's main concern is to prolong the useful life of books through quality binding. Weiss emphasizes the need for the Standard (Class A) and what should be done in the future to keep quality binding within the library binding industry and inferior binding methods out. The Technology Committee of LBI evaluates and investigates binding equipment, procedures, and materials to provide valid technical information to librarians and library binders. LBI's Technology Reports (through 1976) is a chronological record of all evaluations, recommendations, and testing performed by or sponsored by LBI.

The Library Binding Manual, edited by Maurice Tauber and published by LBI, is a guide for librarians, library binders, and students of library science for a sound program in "... maintaining it (a library book) for as long a period, and for as many uses, circulations or withdrawals, as possible at the minimum cost per use or circulation."[1] Jack Phillips, in an article titled "One of Your Best Friends Should Be a Binder," states, "For just a small part of the cost of replacing a book, a binder can 'recycle' that book."[2] The Library Binding Manual defines library binding as seeking to maintain the useful life of a volume that eventually will be expended or replaced. This is differentiated from preservation or restoration because the binding is replaced in library binding rather than the entire volume (binding included) preserved for posterity's sake.[3]

The Library Binding Manual includes all specifications (updated) for the LBI Standard or Class A, both materials and methods. These specifications are based on the "Minimum Specifications for 'Class A' Library Binding," originally issued by the Joint Committee of the American Library Association (ALA) and LBI.[4] These detailed specifications have proven to do the job of maintaining the useful life of library books remarkably well, and Class A has been widely adopted and accepted over the years. Where many volumes with the original publisher's binding were expected to last about 30 circulations [in the early 1970's, and only 10-15 circulations in 1983], if rebound by the Standard, they are expected to last at least an additional 100 circulations.[5] Thus "recycling" with Class A bindings, the Standard, is cost effective.

The above literature and LBI support the need for this study: if library binders must deviate from the Standard, extensive testing and evaluations should be executed for valid information about how the book bindings perform in comparison with the Standard. The books prepared for <u>this</u> study were produced by three different manufacturers, all Certified Library Binders. Since Certified Library Binders (approved and "policed" by LBI) all follow the Standard, the test books were ensured to be of <u>equal</u> high quality except for the variable of binding method. As mentioned before, both paper and condition were two other variables included in this study. Paper of course cannot be specified by binders, and condition (use or aging) can only be indirectly controlled by producing a binding which will withstand time and handling.

In 1961, ALA published <u>Development of Performance Standards for Library Binding, Phase I</u>. ALA and the Special Libraries Association (SLA) sponsored a project, supervised by the Library Technology Project, to survey many libraries for their binding needs. They wanted to identify and define principle categories of library binding, and to create a testing program to establish performance standards, specifications, and acceptance tests for one or more of the categories of library binding to be defined. ALA and SLA's idea was to begin placing more emphasis on books passing performance tests and standards rather than specifying materials and procedures to achieve high quality. The new standards and tests were published in 1966 by ALA, Development of Performance Standards for Library Binding, Phase II. The standards include openability, workmanship, and durability. The traditional LBI Standard passed these performance tests in the toughest category of "heavy use" (minimum of 88-100 circulations).

While Class A had been perfected over the years, testing devices and standard booktesting methods had been slower to come about. The importance to this study of ALA's Phase II is that a testing device called the Universal Book Tester (UBT), developed by W.J. Barrow Laboratory for ALA's durability standard, proved to simulate actual usage or the circulating of a book. It was found that damage to a book normally occurs while handling a book for purposes other than reading it such as dropping the book on a book truck or into a return box, and sliding the book across the table or from a shelf.[6] "To summarize, the types of damage caused by the Universal Book Tester were remarkably similar in nature to those occurring in used books, and for the most part occurred in corresponding proportions."[7]

The UBT was originally designed to be a test in and of itself. After rotating a book in the UBT for a specified period of time (one, two, or three hours), the book is inspected for internal and external damage. The book's score is tallied up from the extent and type of damage and then correlated with a number of circulations. However, the UBT was used in this study only as a means to impart "wear-and-tear" on volumes, to give them the condition of used, in this case at least 100 circulations or 3 hours in the UBT. The Martini Page Pull Tester then determined the book's internal strength, the force required to pull a page loose from the binding as explained in Chapter 4. Therefore, the degree to which a book retained its original strength after continual use was tested.

The Development of Performance Standards for Binding Used in Libraries, Phase III also includes a test method devised to determine openability performance. The test rates books in categories of "poor," "fair," and "superior," with a difference of 1/2 inch between each category. This is a fairly large variation and so ALA's test method was not used for this study. Seija Korhonen's investigation, "Factors Affecting the Strength of a Book," also identifies openability as an important quality of a book to withstand "handling strains."[8] "If a book does not stay open spontaneously, it is forced open, and there is a risk that the block may crack, or the leaves may get loose.

Therefore, in opening the block, the strength of the block is the most relevant strength property."[9] Thus, openability and block (internal) strength, although both measured as separate qualities in this study, are not entirely independent of each other as poor openability may lead to "violent," not-normal library use. And in the other direction, if a very superior openability is found, the larger flexing angle of pages at the binding edge also puts a great strain on the binding. Korhonen, in a section called "Planning of Further Research Work" states, "It is important to define the property 'openability' and to develop measuring methods and devices to quantify it."[10] This study does just that as explained in Chapter 4, "Design Parameters and Methodology."

The above mentioned "Factors Affecting Strength of a Book" and another study, "Faults Appearing in Books in Practical Use" by Seija Ristimaki, both identify three main categories of strength properties formed by a binding. These are: 1) strength of the block, 2) strength between block and the cover, and 3) the strength of the cover. The investigation in this thesis is limited mainly to the strength (and openability) of the book block (internal strength). Cover strengths and strengths between covers and book blocks played the indirect role of "protecting" the book block, and both were assumed to be of equal strengths as all books are bound with Class A.

The literature reviewed thus far has dealt mostly with the binding methods themselves, and materials, procedures, or factors over which library binders have control. Paper is the second factor investigated in this study over which library binders do not usually have control. Korhonen's report, "Factors Affecting the Strength of a Book," revealed that for adhesive bound books, paper outweighs both the factor of spine roughening and also the type of adhesive used in influencing adhesive binding strength. Much research effort, therefore, has gone to studying the specific paper parameters which are responsible for durable adhesive bindings. Kenneth S. Gross' Master's thesis, "Qualities of Uncoated Groundwood Paper Affecting Adhesive Binding Strength," includes an impressive review of literature on this peripheral subject. To summarize the above studies, paper is an important factor to include in binding performance comparisons especially when adhesive binding methods are included. The intent of this thesis is to determine if the binding method plays the most important role in binding strength and if paper is a secondary factor. That is, it was hypothesized that paper (book paper within one basis weight) may have a significant influence on each of the binding strengths but not enough to alter a decision as to the appropriate binding method.

Certain specially formulated PVAs, or cold emulsion polyvinyl acetates, have proven to be the most durable, strong adhesives available for binding today. Three good sources for information on PVAs are Barrow Research Laboratory's Performance/Durability of the Book - IV, "Polyvinyl Acetate (PVA) Adhesives for Use in Library Binding," and two articles by Rebsamen, "Understanding Adhesive Binding Technology," and "Adhesive Binding Library Books." The most recent of these sources, "Adhesive Binding Library Books," relates the history and development of modern PVA cold emulsion adhesives. PVAs originally were developed using "external" plasticizers. Plasticizers give polyvinyl acetal resins (the adhesive) elasticity and flexibility. However, external plasticizers merely adhere to the molecular structure of the PVA material and result in problems of plasticizer migration (poor dispersion). Chemists then developed a way of integrating plasticizers with the PVA molecules. At the point of polymerization, the plasticizers become a permanent part of the chemical substance and the result is good dispersion or no migration problems. "These types of adhesives are defined as copolymers or as 'internally plasticized' cold emulsion adhesives."[11] Rebsamen further states; "Today, modern cold emulsion PVA adhesives are used by all bookbinders for almost all binding operations. Due to the fact that these cold emulsion adhesives contain water, water absorbent materials to be glued will end up with a layer of pure synthetic pellicle. Once dry, they are resistant to water, humidity and heat while maintaining perfect elasticity."[12]

While Korhonen's study, finding paper more important than adhesive used, included two dispersion adhesives and one hot melt, James S. Rich investigated "Cold Emulsion Polyvinyl Acetate Bindability Criteria." Rich also found that paper plays an important part in strength, but within cold emulsion PVAs, spine roughening was more important than type of paper used. Werner Rebsamen, in his article "Adhesive Binding Library Books," asks, "With all the good news on adhesives, why do some adhesive bound library books fail?"[13] A principle reason is that both the type and state of material received by the binders is so varied, Rebsamen states. He also emphasizes that the preparation of the spine (roughening) is critical: "Binders have developed various kinds of roughing techniques for increasing the binding surface, so as to achieve optimum penetration into or around exposed paper fibers. This, combined with double fanning (that is, 'tipping' one page to another) has resulted in adhesive bound products of high quality."[14] The PVA double fanned books for this study were roughened prior to adhesive applications.

Barrow Laboratory in the series of studies called <u>Performance/Durability of the Book</u> has demonstrated that natural aging can be accurately simulated by placing an adhesive or paper in an oven at elevated temperatures for a period of time, a test method used for this study. All aged books were produced by heat-aging.

Werner Rebsamen has published many excellent articles on binding techniques, evaluations of materials, equipment and testing methods, including the aforementioned two on adhesive binding technology. This collection also includes a five-part series titled "A Study of Simple Binding Methods," and "Cleat-lacing: An Alternative Fastening Method for Oversewing?" These articles describe in detail the binding methods to be studied in this research--PVA double fanning, oversewing, and cleat-lacing--with some of their advantages and disadvantages. As well, Rebsamen points out problems the library binding industry is now facing, such as narrower inner margins and inferior materials, and suggests solutions such as evaluating book-binding by testing. The Dudley A. Weiss Bookbinding Laboratory at RIT directed by Rebsamen includes many testing devices and test methods for such performance comparisons. (All testing for this thesis was done at the RIT/LBI laboratory.) Rebsamen's articles "LBI Booktesting Laboratory Attracts Publishers and Book Manufacturers," "Booktesting Laboratory Evaluates Machinery, Materials, Techniques," and "Upgrading Binding Quality: Report on the New RIT/LBI Booktesting Laboratory" all explain the important function of testing books and how these tests are done. Rebsamen states, "... the purpose of the new [1976]

Laboratory is to test and evaluate new binding methods and materials, including adhesives, to explain and demonstrate the optimum characteristics of appearance and performance of a good library bound volume."[15]

One final source of information included for this review is Jack Bendror's Technology and Testing of Library Bound Books with an introduction by Rebsamen. It is one of the most recent, comprehensive reports on the state of the art of performance testing of library bound books and directly related to this study. Bendror concluded that adhesive cleat-laced (with cold emulsion PVA) bindings and PVA cold emulsion binding with fanning (double fanning) were both preferable to either hot melt bindings or PVA without fanning when considering alternate methods for narrow inner margin volumes intended for library use. Bendror explains what he calls the "battle of the margin" and the problems with recent product mix changes. The idea of an Optimum Binding Method Index is introduced for occasions when oversewing is not appropriate. "The binder must search for alternate adequate methods (other than costly hand sewing) of fastening pages together and still be able to give his library customer a product with superior strength and durability than that offered initially by the edition binder."[16]

Bendror also describes testing methods including the ones used in this study (except openability) which are explained in the next chapter, "Design Parameters and Methodology." There are no universally accepted strength tests. However, throughout the literature reviewed, including peripheral studies not mentioned here, the page pull method of testing book block strength (or investigating factors affecting strength) is most common.

FOOTNOTES FOR CHAPTER 3

[1]Maurice F. Tauber, ed., *Library Binding Manual* (Boston: Library Binding Institute, 1972), p. 6.

[2]"Jack" H.T. Phillips, "One of Your Best Friends Should Be a Binder," *The Library Scene* (June 1978), p. 23.

[3]Tauber, pp. 5-6.

[4]*Ibid.*, p. 6.

[5]*Ibid.*, p. 3.

[6]American Library Association, Library Technology Project, *Development of Performance Standards for Library Binding, Phase II*, LTP Publications No. 10 (Chicago: American Library Association, 1966), p. 30.

[7]*Ibid.*, p. 33.

[8]Seija Korhonen, "Factors Affecting the Strength of a Book," 14th IARGAI Conference, Marbella, Spain (Finland: Graphic Arts Research Institute, 1977), p. 5.

[9]*Ibid.*, p. 5-6.

[10]*Ibid.*, p. 18.

[11]Werner Rebsamen, "Adhesive Binding Library Books," *The New Library Scene* (January/February 1983), p. 10.

[12]*Ibid.*, p. 11.

[13]*Ibid.*

[14]*Ibid.*

[15]Werner Rebsamen, "Upgrading Binding Quality: Report on the New RIT/LBI Book Testing Laboratory," *The Library Scene* (December 1976), p. 27.

[16]Jack Bendror, *Technology and Testing of Library Bound Books* (Rochester, New York: Graphic Arts Research Center, 1976), p. 2.

CHAPTER 4

DESIGN PARAMETERS AND METHODOLOGY

Book Preparation

At this point it would be helpful to begin referring to Table 1, Book Treatment with Identification by Coding, to understand the combinations of books prepared for testing. In part, the analysis of variance statistical method, described later in this chapter, dictated the quantity and types of books bound for this study to ensure valid results.

Fifty-four books were bound to yield various combinations of the three factors: 1) binding method, 2) paper, and 3) condition. The three methods of binding were: 1) oversewing, 2) PVA double fanning, and 3) Smyth cleat-lacing. The three papers chosen were: 1) uncoated, Warren's Old Style Offset, 60 lb (25 x 38), 2) dull, Warren's Patina Matte, 60 lb (25 x 38), and 3) glossy, Warren's Casco Gloss, 60 lb (25 x 38). The three conditions were: 1) new or not "tampered" with after being received from the manufacturer, 2) used or "tumbled" by the Universal Book Tester (UBT) described later in this chapter, and 3) heat aged, accelerated aging by elevated temperature also described later in this chapter. Two books were bound for every combination of the above factors yielding 54 test books: 2 replicates X 3 binding methods X 3 papers X 3 conditions = 54 bound books.

In the article "Bookbinding Testing Laboratory Evaluates Machinery, Materials, Techniques," Werner Rebsamen states, "In comparison performance testing, it is most important that the books be of equal dimension, weight and paper. Otherwise, there are so many variables that fair judgment becomes difficult. The ideal testing book should weigh about three pounds and be approximately 6 X 9 inches in size."[1] Each of the 54 books were of equal weight (2.5 lbs. plus board and cover) and dimension (6 X 9 inches trim size). The page count of all volumes was also uniform as the uncoated, dull, and glossy papers all have a 60 lb basis weight (25 X 38). There were three different thicknesses of the book block depending on which of the three papers were bound: the book blocks with uncoated were 1-13/16 inches, with dull 1-3/8 inches, and with glossy just 1 inch. A uniform thickness would have necessitated forfeiting both equal page count and equal weight. The UBT procedure destroys heavy books at a greater rate than light ones.[2] Eighteen volumes remained in the UBT for an equal time segment of three hours, said to be approximately a minimum of 100 circulations. Therefore, uniform weight was essential and thickness forfeited. All volumes were bound with paper grain parallel to bindfold.

The above design parameters were ideal for the testing procedures and, just as important, yield books with qualities that are commonly produced by the publishing industry. Also, the design did not go to extremes for any of the binding methods. For example, an adhesive bound book of more than 1-1/2 to 2-1/2 inches (depending on its weight) was already known to be undesirable.[3] Thus, the testing was done in an area where the Optimum Binding Method was definitely in question.

The paper was purchased and trimmed to 6-1/4 X 9-1/4 inch loose leaves, the paper packaged in blocks (2.5 lbs.), and shipped to three different commercial binders. Paper samples to be oversewn were sent to one binder (18 books), double fanned to another (18 books), and cleat-laced to the third (18 books). Each is a certified library binder. Specific instructions were given to each binder to bind the books in a commercial fashion. Class A specifications were followed for all 54 books with the exception of the method of affixing pages. For both the double fanned and cleat-laced volumes, the PVA was specified by the manufacturer to ensure high quality (Eluid LB for cleat-laced and Planatol BB for double fanned). All volumes were trimmed to 6 X 9 inches, rounded and backed, backlined, and bound with grade F Buckram over .098 binders boards. The backs of the double fanned volumes were roughed prior to adhesive applications.

All testing, as described in the following sections, was done at the Dudley A. Weiss Book Testing Laboratory at RIT.

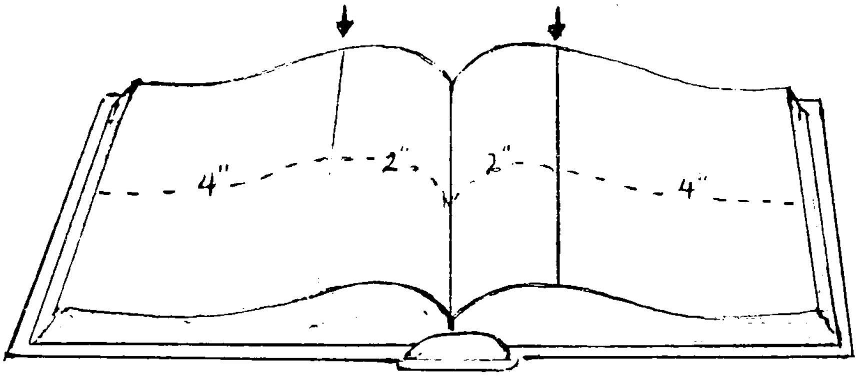
Openability

In 1966, ALA published Development of Performance Standards for Binding Used in Libraries, Phase II as discussed in the Literature Review, Chapter 3. This book describes ALA's standard test apparatus and testing method for openability. The ALA method furnishes a very simple and reasonable way to guage the openability of a book[4], defined as the ability of a bound book to be opened easily and to lie open unaided.[5] Briefly the test involves placing a clear plastic Test Plate (9 X 12 inches),[6] with lines scored at half-inch intervals, on top of a book gently opened to its innermost pages. A weight is then placed on top of the Test Plate. The distance between the lines on the Test Plate that actually touch the page are read, the greater the distance, the poorer the openability is rated.[7] The rating's precision is only to the nearest 1/2 inch with three categories of "poor", "fair" and "superior." For needs of this study, a more precise method was devised to rate books to the nearest 1/32 inch. This has been named the "Photocopy Openability Test" both because the test is performed with the use of a photocopy machine and because photocopying has become a menace to books that do not have good openability.

The Photocopy Openability Test is very simple. Each of the fifty-four books was opened exactly to its center. A line was drawn on each of the two facing pages exactly four inches from the outer edge, parallel to the binding edge as shown in Figure 5, Book Preparation for Openability Photocopy Test. The volume was then placed face down on a photocopy machine, a one pound weight placed in the center of its spine (for uniform, slight down-pressure), and a photocopy taken. The distance between the two lines on the photocopy was then measured and recorded to the nearest 1/32 inch. The photocopy machine was previously tested for 100 percent reproduction size.

Each book then, started with a maximum potential of a four inch openability measurement, two inches for each of the facing pages. This also is noted in Figure 5. The scores of the two replicates for each paper/binding/ condition category were averaged for one score to be graphed and analyzed. The six scores for each binding/ paper category were also averaged to analyze the results disregarding condition. This was also graphed. The openability testing was done prior to the page pull strength testing.

Lines drawn 4 inches from each outer edge.



(Drawing by Elizabeth Watson)

FIGURE 5. BOOK PREPARATION FOR OPENABILITY PHOTOCOY TEST

Page Pull Strength Test(s)

The object of page pull testing is to measure the force required to pull a single page out of its binding. The piece of equipment available in the planning stages of this study, designed specifically for page pull testing, had an electronic malfunction just prior to the proposed test start date. The problem was later solved when a Swiss-built, Martini Page and Flex Tester was installed at the Dudley A. Weiss Book Testing Laboratory at RIT. In the interim, this study became a search for an adequate alternate testing device. The alternate equipment investigated is worth mentioning here to help others avoid some testing pitfalls.

At an outside testing laboratory, an electronically equipped tensile tester is commonly used for page pull tests in measuring adhesive binding strength of perfect bound paperback books. It seemed plausible to tailor the test for hardbound bookbinding. The covers of a paperback are each (front and back) opened 180°, back-to-back, for securing in the lower clamping device as shown in Figure 6, Tensile Tester for Page Pulls, Paperbacks. The upper clamp grips a single page (other pages "fan-out") and the upper clamp is raised upward, pulling the page out of its binding. Its measurement is recorded in kilograms of force (conversion to pounds per linear inch is possible).

The covers of a casebound book, such as ones in this study, should not be forced to open 180° and clamped together. So, a "clamping table" was built to replace the existing removable lower clamp. As shown in Figure 7, Lower Clamping Table, the pages and covers to either side of the test pages were opened to approximately 90° and held firmly to the table by two clamps. This allowed a single page to be pulled from the book block.

With the new lower clamp now working properly, one book (A3B2C2[b]) was tested and a second problem surfaced which led to "scrapping" this testing method altogether. The upper clamp, not being wide enough to grab the entire

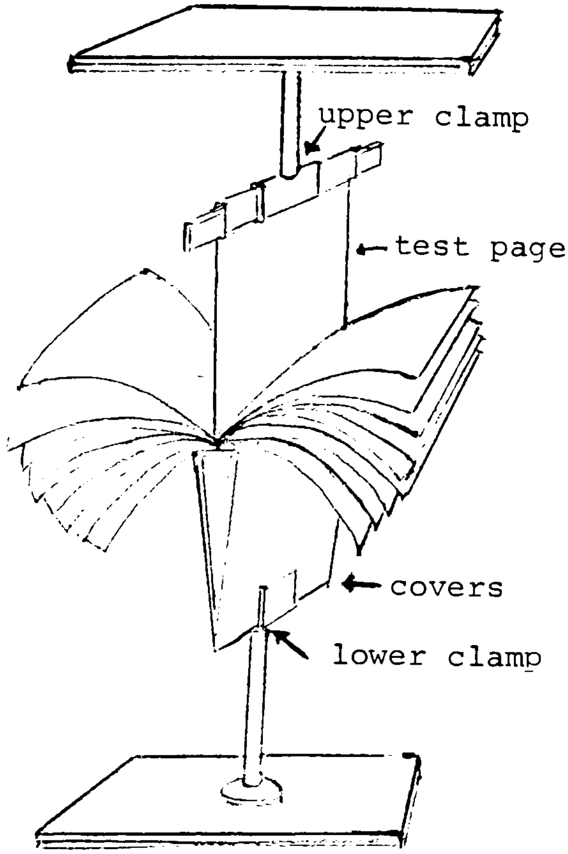


FIGURE 6. TENSILE TESTER FOR PAGE PULLS, PAPERBACKS

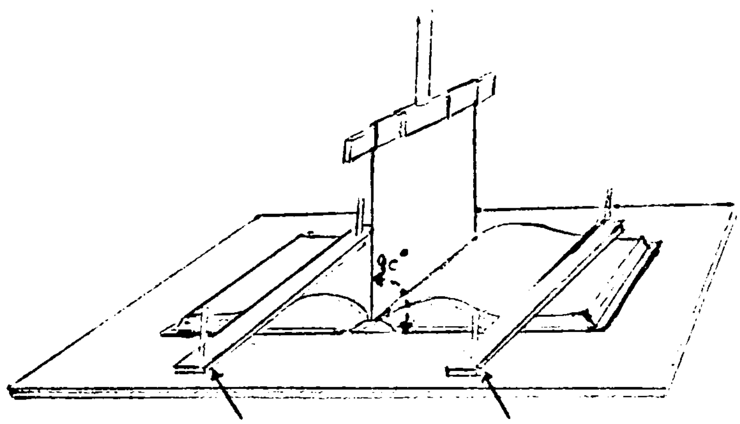


FIGURE 7. LOWER CLAMPING TABLE

(Drawings by Elizabeth Watson)

length (nine inches) of the page, was used in conjunction with a flat ruler-like bar. In previous booktesting, a page was "rolled" tightly around this bar once and then clamped by the upper clamp as shown in Figure 8, Upper Clamp Device, to obtain an even pull along the entire length of the page. This method, for the one book tested, caused the force to be unevenly distributed across the page, also indicated in Figure 8. The pages tore at or near the upper clamp as shown in Figure 9, Upper Clamp Failure. The failure evidently had not been demonstrated with adhesive bound books with less binding strength and with shorter page length.

The above page pull method involved modifying (unsuccessfully) the equipment to suit the needs of booktesting. The Martini Page and Flex Tester, however, was designed specifically as a device for page pull (and flex) testing. This testing unit is considered to be one of the most accurate and reliable for booktesting.[8] A book is opened to the page that is to be tested and loaded, face down and flat, onto the table as shown in Figure 10, Schematic Representation of the Martini Pull and Flex Tester. The test page is inserted through a slot and then clamped in a jaw. The motor increases tensile stress on the page by slowly pulling the jaw downward until the page becomes loose from its binding. The tensile strength or force is recorded in kilopounds (kp); one kp is equal to

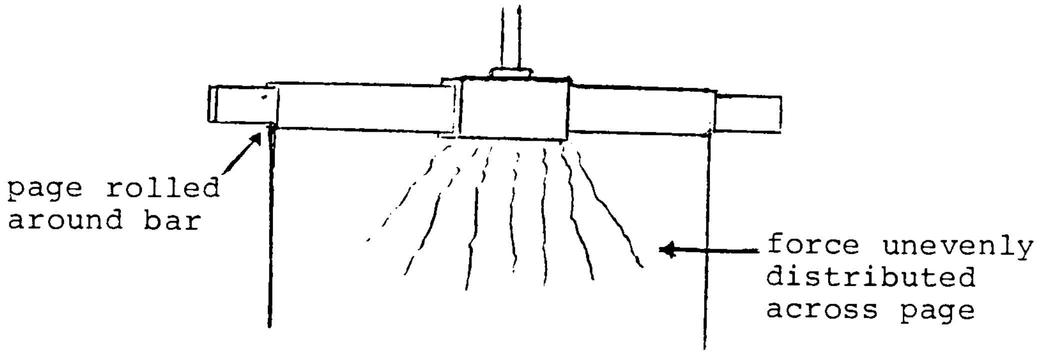


FIGURE 8. UPPER CLAMP DEVICE

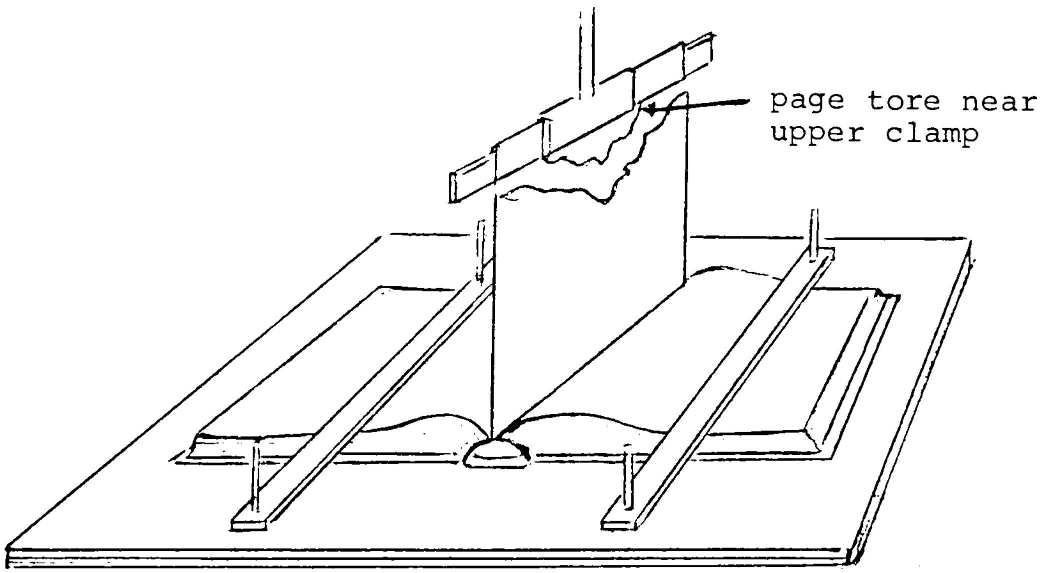


FIGURE 9. UPPER CLAMP FAILURE

(Drawings by Elizabeth Watson)

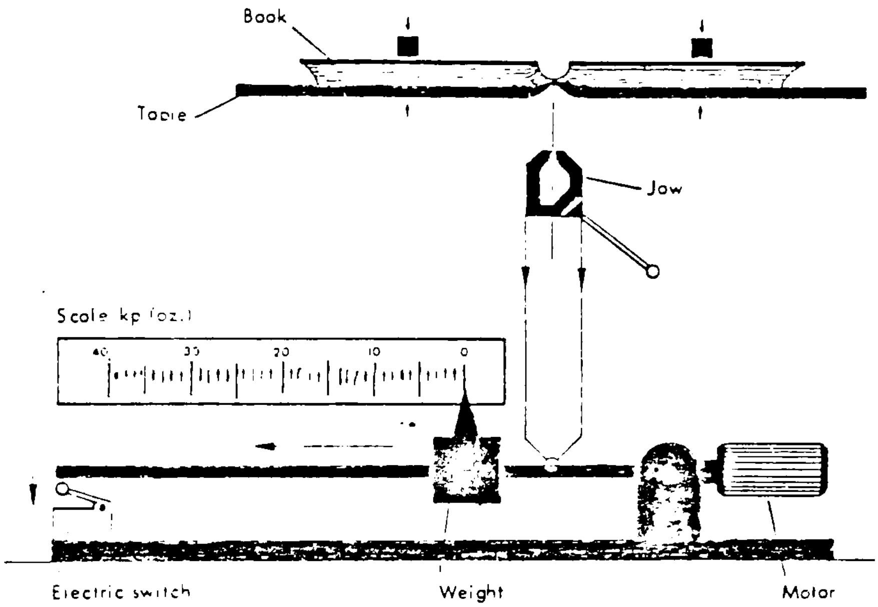


FIGURE 10. SCHEMATIC REPRESENTATION OF THE MARTINI PULL AND FLEX TESTER

3-1/2 ounces. The total force is converted to pounds and then divided by the height of the book (9 inches) to give the measurement or score in standard units of pounds per linear inch, sometimes written as "lbs/in" in this paper.

For each of the fifty-four test books, seven pages were pulled, two from the front, two back pages, and one from the center. The Martini Tester Instruction Manual recommends seven page pulls for each book, discarding the highest and lowest scores, and averaging the remaining five scores.[9] However, for this study, the highest and lowest scores were kept because analysis of variance, ANOVA, is an analysis of the differences in the scores and attributes variance within one book to error (as explained later in this chapter). The same operator pulled all 378 pages (7 X 54) to ensure uniformity of measurements. The books were tested in a random sequence.

It should be noted that one book's scores were not used at all for strength analysis ($A3B2C^b$). This was the book used for trying the tensile page pull testing and suspected to be damaged by the tests. The results from the Martini Tester were much lower for this book than its replicate. Page pull tests are considered to be destructive and the reason why separate sets of books were made for each condition. For example, the new books were tested and <u>not</u> re-tested after aging. Rather, a second set of books was used for aging and then testing.

Treatment of Books for Aged Condition

Eighteen books were subjected to the heat aging test: two books (replicates) from each of the nine binding method and paper combinations. Referring to Data Table 1, these are the books with a "C3" code. Heat aging is a test to determine the stability (flexibility retention) of an adhesive or its resistance to embrittlement over a period of time. The same deteriorating effects (chemical reactions, etc.) that occur in natural aging of adhesives at room temperature also occur at elevated temperatures but at a much faster rate.[10] Heat aging can also expedite the detection of important changes in paper. Although the oversewn volumes are not adhesive bindings, the aging of the paper alone may affect binding strength. Therefore, books of all three binding methods (6 of each, total 18) were placed in an oven set at 65°C. for 72 consecutive hours. This is said to be equivalent to a minimum of five years of natural aging.

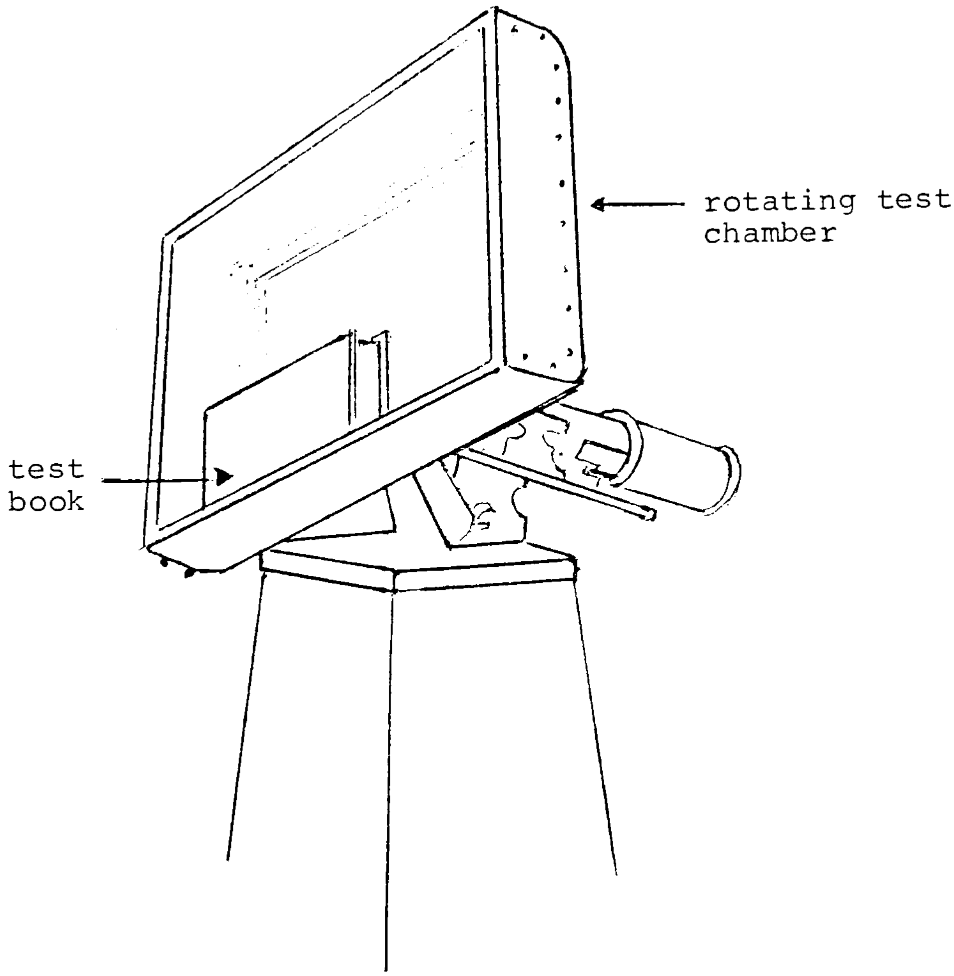
Treatment of Books, Universal Book Tester

To test the effect of a book being handled or circulated in or out of a library on its binding strength, the Universal Book Tester or UBT (described in Literature Review) was employed to produce used books. Eighteen books were subjected to this treatment: two books (replicates) from each of the nine binding and paper combinations. Again, referring to Data Table 1, these are all the volumes with a code that includes "C2."

Briefly, the UBT consists of a rectangular aluminum test chamber supported and rotated by a shaft attached perpendicular to the center of the bottom as shown in Figure 11, Illustration of the Universal Book Tester. The chamber is lined with a stainless steel fabric for abrasion when the book is rotating. The book also receives repeated impacts. The drive shaft rotates the chamber at a 20° angle approximately 20 rotations per minute.[11] Each book was placed into identical chambers for three hours of "tumbling." After confirming an equal number of rotations for all books, this set of books was now ready first for the openability test, and second for the strength tests. Detailed instructions for the durability standard testing procedures (UBT) can be found in ALA's <u>Development of Performance Standards for Binding Used in Libraries, Phase II</u>.

<u>Analysis of Variance</u>

To analyze properly the effect of binding method, paper, and condition on binding strength, a statistical method called "analysis of variance," commonly abbreviated "ANOVA," was employed. ANOVA is a test of means (averages)



(Drawing by Elizabeth Watson)

FIGURE 11. ILLUSTRATION OF THE UNIVERSAL BOOK TESTER

and a technique by which one can assign to each of the factors tested some portion of the total variability in the data. After carrying out the analysis, tests of significance (F Ratio) are done to find whether or not the variance assigned to a specific factor is greater than that which can plausibly be assigned to error.[12] Error is a known value computed from the data (response variables). The response variable in this case is lbs/in, one page pulled from a volume. The significance tests were used with an alpha risk of five percent ($\alpha = 0.05$) meaning that there was only a five percent probability of being wrong[13] when, for example, it was determined that the paper factor had a significant effect on binding strength.

The specific ANOVA utilized is a three factor, three level, crossed, and replicated one. The three factors each with three levels are:

1. PAPER
   1. Uncoated
   2. Dull
   3. Glossy
2. BINDING METHOD
   1. Oversewn
   2. PVA Double Fanned
   3. Cleat-Laced
3. CONDITION (TREATMENT)
   1. New
   2. Used
   3. Aged

<u>Crossed</u> means that the tests were run at each level in combination with every other level, yielding twenty-seven different combinations or categories of books for strength testing (3 X 3 X 3 = 27). The testing was also <u>replicated</u>, allowing for a more sensitive ANOVA because it provides the estimate of error needed for the F Ratio. In this case, two volumes were prepared for each of the twenty-seven categories for a total of fifty-four (54) test books. Replication also occurred by pulling seven pages from each book. In analyzing the results, the replicate books' means were quite close in strength results; therefore, the two sets of seven scores were collapsed so there were fourteen replicate response variables (page pull, lbs/in) in each of the twenty-seven categories.

The mathematical model for this three factor, three level, crossed, and replicated experiment is:

$$x_{ijkl}{}^{*} = u + A_i + B_j + C_k + (A \times B)_{ij} + (A \times C)_{ik} + (B \times C)_{jk} + (A \times B \times C)_{ijk} + E_{l(ijk)}$$

Conceptually, this means a single observation or response variable, x_{ijkl}, is hypothesized to be accounted for by nine possible influences.[14] These nine are:

1. u, the general average (mean) of the population of all books tested

---

* The letters ij and k stand for different levels of the factors, l stands for replicates.

2. A_i, a possible paper effect

3. B_j, a possible binding method effect

4. C_k, a possible condition effect

5. $(A \times B)_{ij}$, a possible paper/binding method interaction effect

6. $(A \times C)_{ik}$, a possible paper/condition interaction effect

7. $(B \times C)_{jk}$, a possible binding method/condition interaction effect

8. $(A \times B \times C)_{ijk}$, a possible paper/binding method/condition multiple interaction effect

9. $E_{l(ijk)}$, Error

A null hypothesis (H_o) can be stated for each of the effects (2 through 8) above, each stating that the effect of the factor or interaction is zero or attributed to error at any level.[15] These are: H_o:A_i=0, H_o:B_j=0, H_o:C_k=0, H_o:$(A \times B)_{ij}$=0, H_o:$(A \times C)_{ik}$=0, H_o:$(B \times C)_{jk}$=0, and H_o:$(A \times B \times C)_{ijk}$=0. These null hypotheses are what the ANOVA tests, by means of the page pull tests.

FOOTNOTES FOR CHAPTER 4

[1]Werner Rebsamen, "Bookbinding Testing Laboratory Evaluates Machinery, Materials, Techniques," Book Production & Magazine Production (May 1977), p. 66.

[2]Ibid.

[3]Werner Rebsamen, "Understanding Adhesive Binding Technology," The Library Scene (March 1978), p. 16.

[4]American Library Association, Library Technology Project, Development of Performance Standards for Library Binding, Phase II, LTP Publications No. 10 (Chicago: American Library Association, 1966), p. 37.

[5]Ibid., p. 6.

[6]Ibid., p. 12.

[7]Ibid., p. 6.

[8]Werner Rebsamen, "Performance Comparison of Oversewn, Double Fanned and Cleat-Laced Bindings," The Library Scene (July/August 1982), p. 20.

[9]Martini Tester Instruction Manual, p. 21.

[10]W.J. Barrow Research Laboratory, Permanence/Durability of the Book, Volume IV, "Polyvinyl Acetate (PVA) Adhesives for Use in Library Bookbinding," (Richmond, Virginia: W.J. Barrow Research Laboratory, 1965), p. 32.

[11]ALA, Phase II, p. 14.

[12]Albert D. Rickmers and Hollis N. Todd, Statistics: An Introduction (New York: McGraw Hill Book Company, 1967), p. 179.

[13]Ibid., p. 64.

[14]Ibid., pp. 172-173.

[15]Ibid., p. 182.

CHAPTER 5

ANALYSIS OF DATA AND RESULTS

Openability Photocopy Test Results

The Openability Photocopy Test revealed that there are definitely differences in the ability of a book to lie open flat depending upon the binding method of a volume: oversewn, double fanned, or cleat-laced. The double fanned openability was superior to both cleat-laced and oversewn for all three papers. Cleat-laced came in second best with oversewn slightly behind. Double fanned was the only method that showed "dramatic" differences between the uncoated, dull, and glossy papers. Although openability did usually change depending upon the condition of a volume (new, used, aged), the relationship between the three binding methods' performance remained fairly constant.

One must keep in mind that this performance comparison was done using papers of the same basis weight (60 lb) and of the same paper grain direction (parallel to binding edge). It would be unwise to conclude that the relationships and levels of openability would hold true for all papers and basis weights. Also, to put the analysis of results in perspective, the largest openability difference detected (or range found) between two binding methods (same paper and condition) was about 1-5/16". The lowest actual score was 2-6/32" and largest 3-15.5/32". All raw scores, averaged scores, and scores coded for the graphs in this chapter are contained in Appendix B, Tables 2-6.

The overall results of the Openability Photocopy Tests are shown by a graph in Figure 12, Openability Overall Results. This is a performance comparison of openability disregarding the conditions of the volumes. Each score was computed by averaging all six raw scores within one binding method/paper category. For example, the oversewn uncoated (A1B1) measurements were averaged from the two new books ($C1^a$, $C1^b$), two used books ($C2^a$, $C2^b$), and two aged books ($C3^a$, $C3^b$). The score was then coded by subtracting 2-6/32" (the lowest score computed for one category). For example, 2-13/32" - 2-6/32" = 7/32". The coded score here is 7. The larger the score, the better the openability is. The lowest actual score of 2-6/32" received a coded score of 0.

The Figure 12 graph reveals that double fanned books have the best overall openability (B2>B1 and B2>B3). This relationship holds true for the uncoated, dull, and glossy stocks. However, the degree of double fanned superiority changed with paper; the range of the three scores was 19/32" or a little over 1/2". The double fanned performance increased 7.5/32" from uncoated to dull and another 11/32" from dull to glossy (A1 = 2-29.5/32", A2 = 3-5/32", A3 = 3-11/32"). The lowest double fanned score is greater than the highest score of either cleat-laced or oversewn bindings. The uncoated double fanned score is only 4/32" better than cleat-laced, and 13/32" greater than oversewn. However, appreciable differences in openability are demonstrated with the glossy paper where the score is 23/32" greater than cleat-laced and 36/32" greater than oversewn.

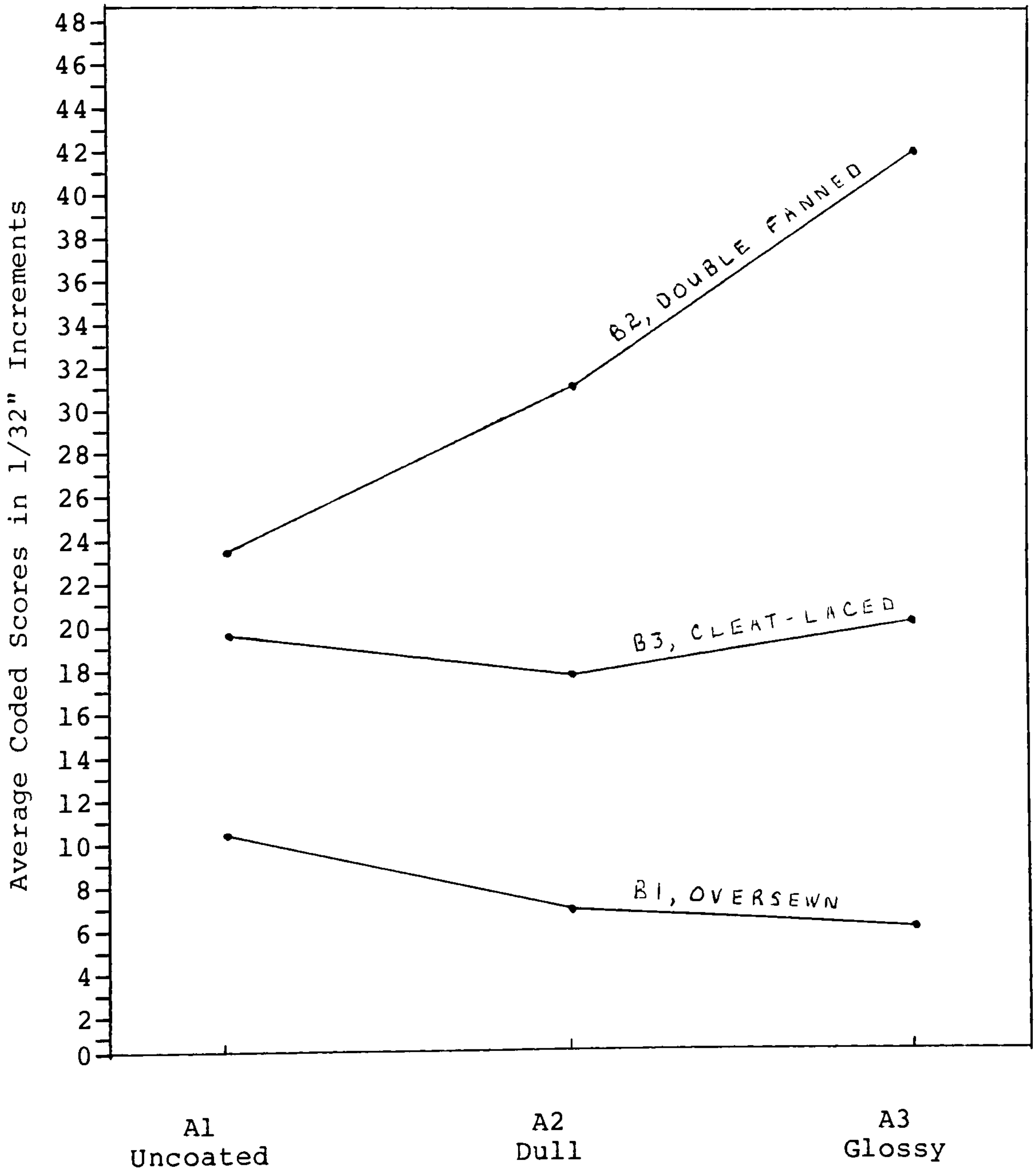
Again referring to Figure 12, cleat-lacing proved to yield fairly consistent results across all papers with a small range of 4/32": uncoated 2-24/32", dull 2-25.5/32", and glossy 2-21.5/32". The cleat-laced openability is approximately 1/4" better than oversewn across all papers, a small but noticeable difference. The oversewn also yielded consistent results with 2-16.5/32" for uncoated, 2-13/32" for dull, and 2-12/32" for glossy.

Openability performance comparisons were also individually graphed for each of the three conditions: new, used, and aged. These are depicted in Figure 13, Openability, New Books; Figure 14, Openability, Used Versus New Books; and Figure 15, Openability, Aged Versus New Books. The scores represent the average of two scores for each binding method/paper/condition afforded by the inclusion of replicate books.

FIGURE 12

OPENABILITY OVERALL RESULTS

Graph of Scores Averaged (C1, C2, and C3)
For Each Binding Method and Each Paper

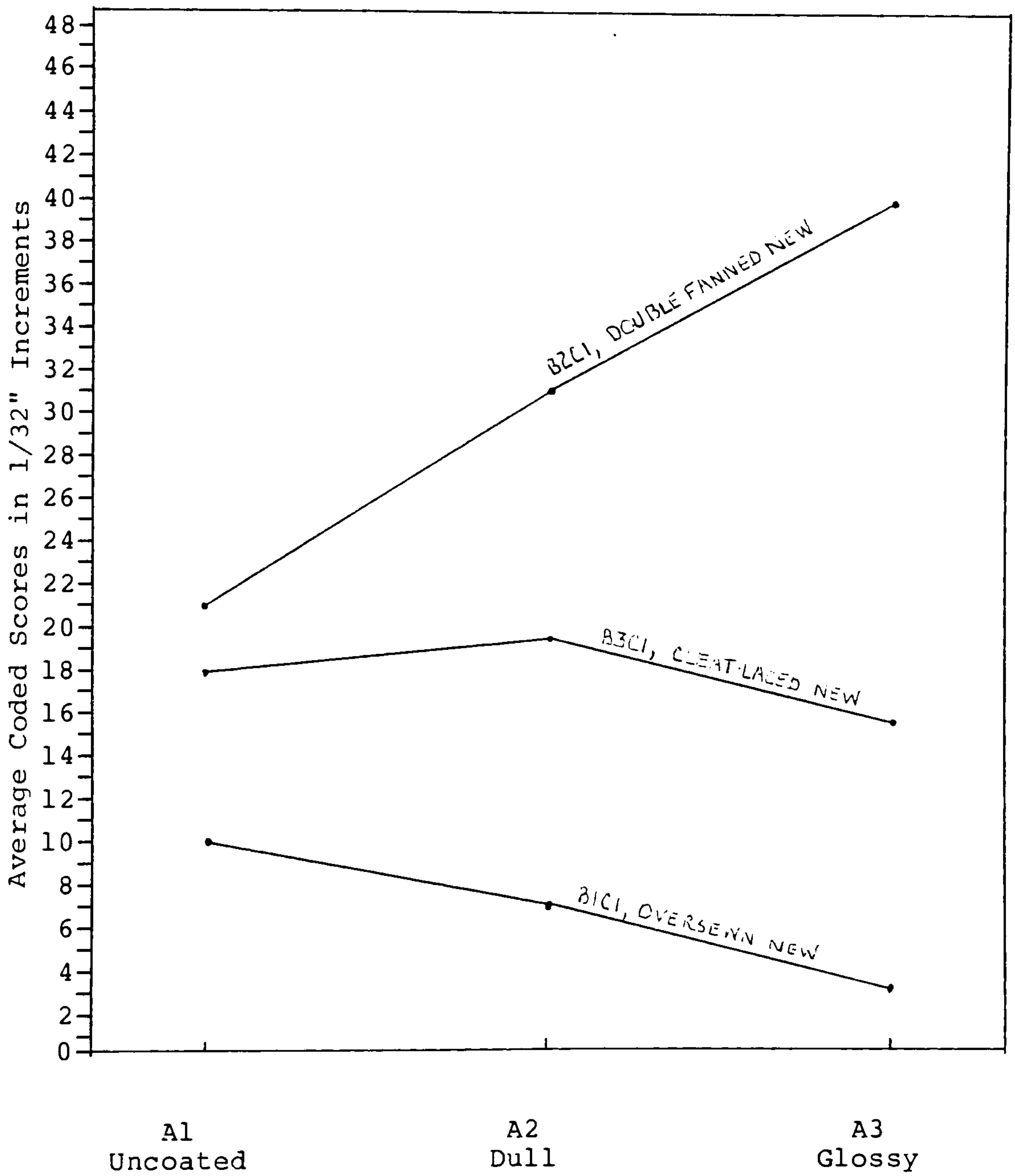


(Appendix B: Table 2 lists raw scores, Table 3 lists average scores, actual and coded)

FIGURE 13

OPENABILITY, NEW BOOKS

Graph of Average Scores (Replicates) of New Books

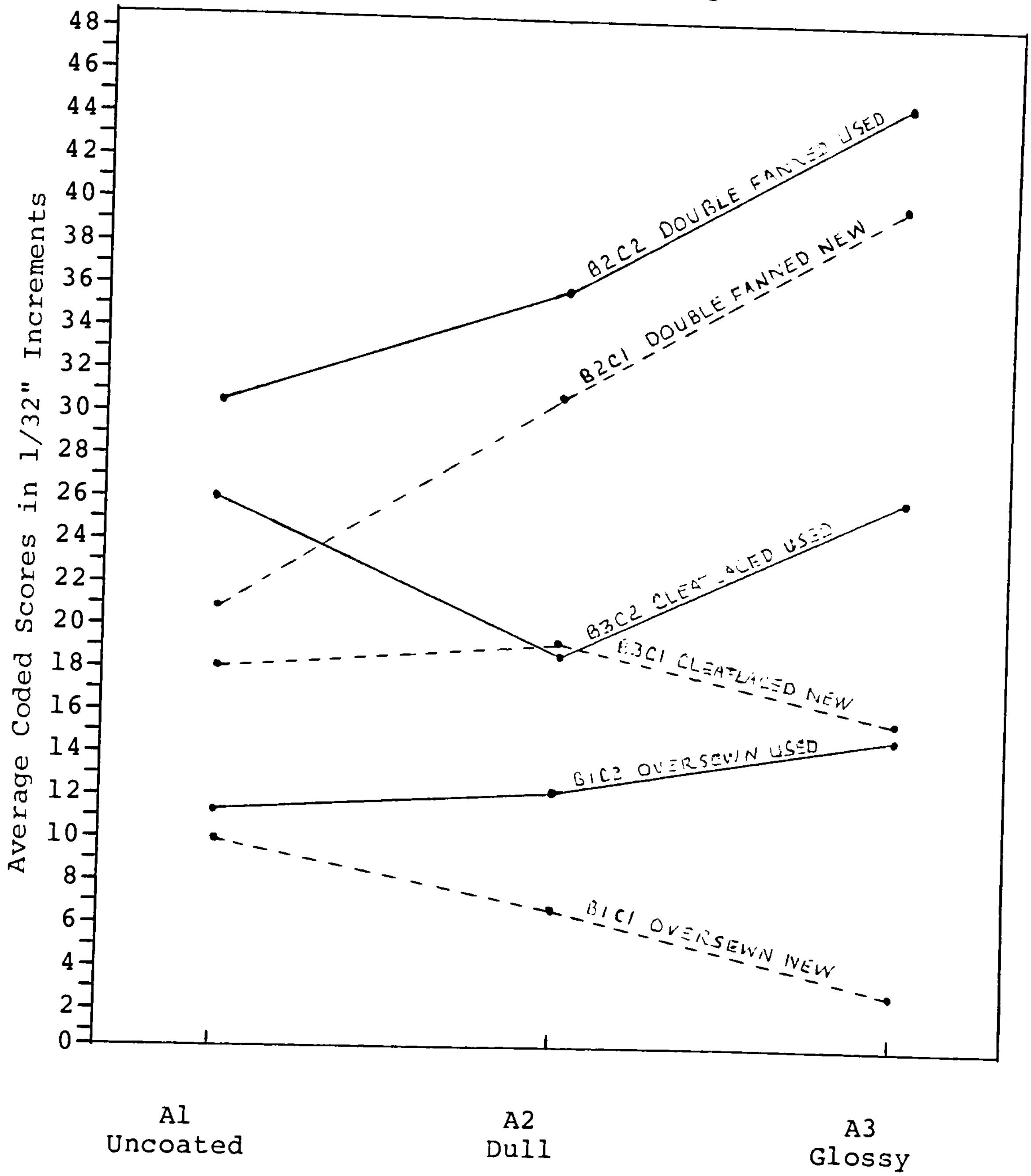


(Appendix B: Table 4 lists new book scores, actual and coded)

FIGURE 14

OPENABILITY, USED VERSUS NEW BOOKS

Graph of Average Scores (Replicates) of Used and New Books

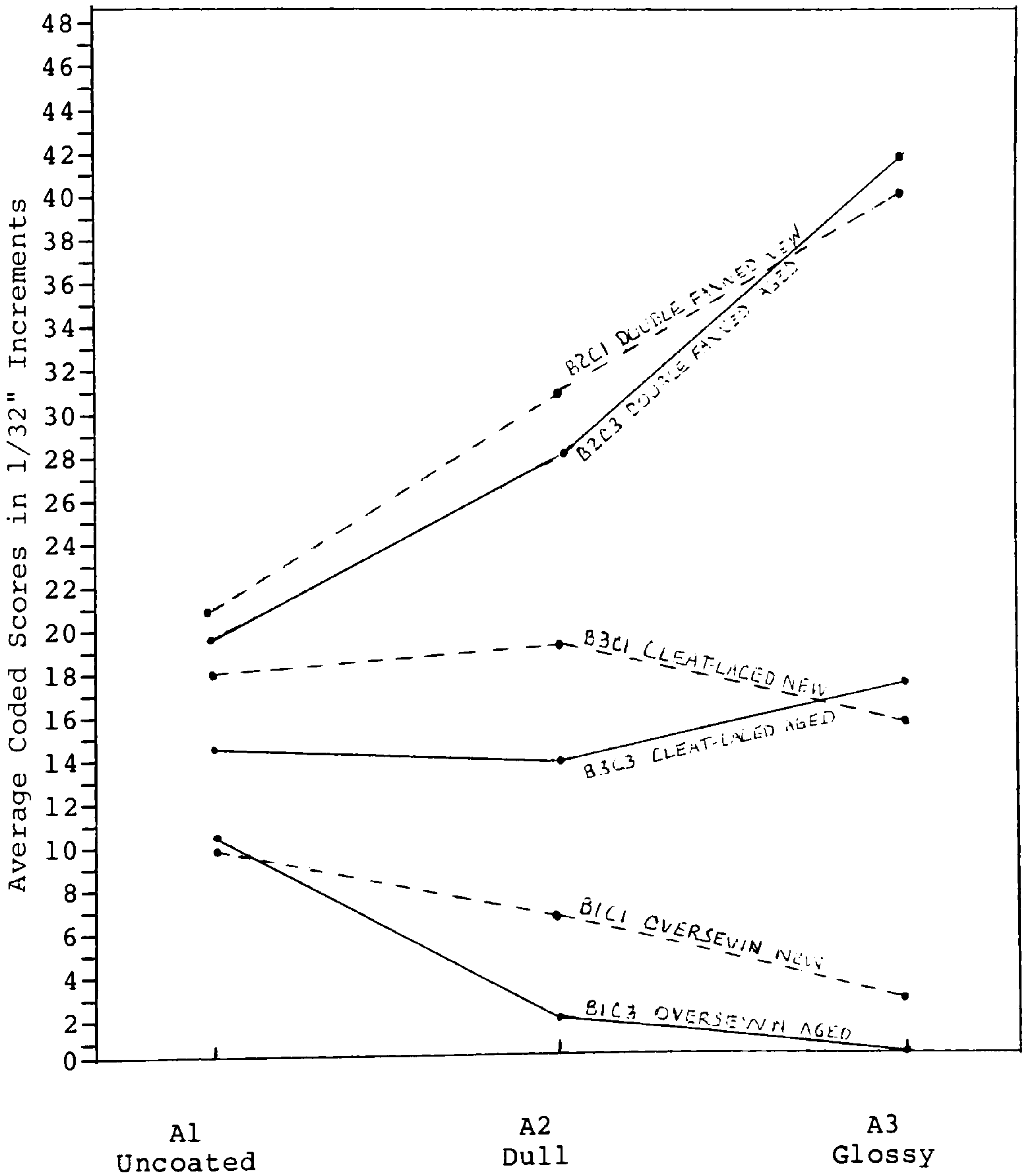


(Appendix B: Table 5 lists used book scores, and Table 4 lists new book scores; actual and coded)

FIGURE 15

OPENABILITY, AGED VERSUS NEW BOOKS

Graph of Average Scores (Replicates) of
Aged and New Books



(Appendix B: Table 6 lists aged book scores, and
Table 4 lists new book scores;
actual and coded)

Figure 13 reveals that the new books' (C1) averages have approximately the same scores as the averages of all conditions (Figure 13: C1, C2, C3). Therefore, the relationships between new volumes and general level of openability of new volumes are approximately equal to the overall average shown in Figure 12.

The graph in Figure 14 plots the averages of the used books (C2) against the new books (C1) to show the effect of use on openability. In most instances, this condition (used) caused the books to have a slightly better openability. The dull cleat-laced and uncoated oversewn did not change appreciably. The largest increase occurred in the glossy oversewn volumes, 12/32".

The graph in Figure 15 shows the effect of heat aging on the openability scores, plotting aged versus new. This graph shows a general trend for aging to decrease openability. And this decrease occurs more with the uncoated or dull cleat-laced, and with the dull or glossy oversewn than with the double fanned books. The largest difference detected due to aging was only 5.5/32".

It appears that the reason the new books' scores so closely parallel the overall average scores (across all conditions) is that age and use tend to cancel each other out. This study did not contain a set of books both aged and used at the same time, therefore it cannot be said this is true in a real situation when a book is both older and has been used or circulated a great deal.

Strength (Page Pull) Test Results

The Martini Page Pull Testing revealed that all of the volumes tested (54) exceeded the tensile page strength of 4.0 lbs/in, Library Binding Institute's minimum requirement for a rating of "Excellent"[1] for binding strength. Therefore, the two popular methods PVA double fanning and Smyth cleat-lacing remain among those at the "top-of-list" of alternate binding methods for library use, for books within the parameters and design (6 X 9 inches, 60 lb paper, etc.) set forth in the preceding chapter. However, the results did vary from the lowest score of 4.26 lbs/in (glossy, used, cleat-laced) to the best score of 8.50 lbs/in (dull, used, double-fanned). This range of 4.24 lbs/in is a considerable difference in binding strengths; some combinations of binding method, paper, and condition were definitely (and statistically significant) more "Excellent" than others.

The ANOVA and interpretation of ANOVA (found in Appendix C, Tables 13-14) show that these variations in results were due to factors and interactions other than what could be chalked up to error. The binding method factor (three levels) had a statistically significant influence on binding strength; the variation, in part, was due to this main single factor ($F_{2,344,0.05} = 3.07 < 22.061$). Similarly, paper (three levels) also had a significant influence on binding strength with the largest F Ratio ($F_{2,344,0.05} = 3.07 < \underline{67.995}$). Condition (also three levels), the third single main factor, did <u>not</u> cause significant variation in binding strength by itself ($F_{2,344,0.05} = 3.07 > 0.067$). The ANOVA also shows that each of the three combinations, two-way interactions hypothesized to influence the binding strengths, did prove to be significant. That is, the paper/binding method interaction ($F_{4,344,0.05} = 2.45 < 8.363$), the paper/condition interaction ($F_{4,344,0.05} = 2.45 < 3.37$), and the binding method/condition interaction ($F_{4,344,0.05} = 2.45 < 3.75$) were all statistically significant. So condition did matter in the two-way interactions, but not by itself. The multiple (three-way) interaction of paper/binding method/condition proved to be an insignificant influence ($F_{8,344,0.05} = 2.01 > 1.1621$).

<u>Main Factors</u>

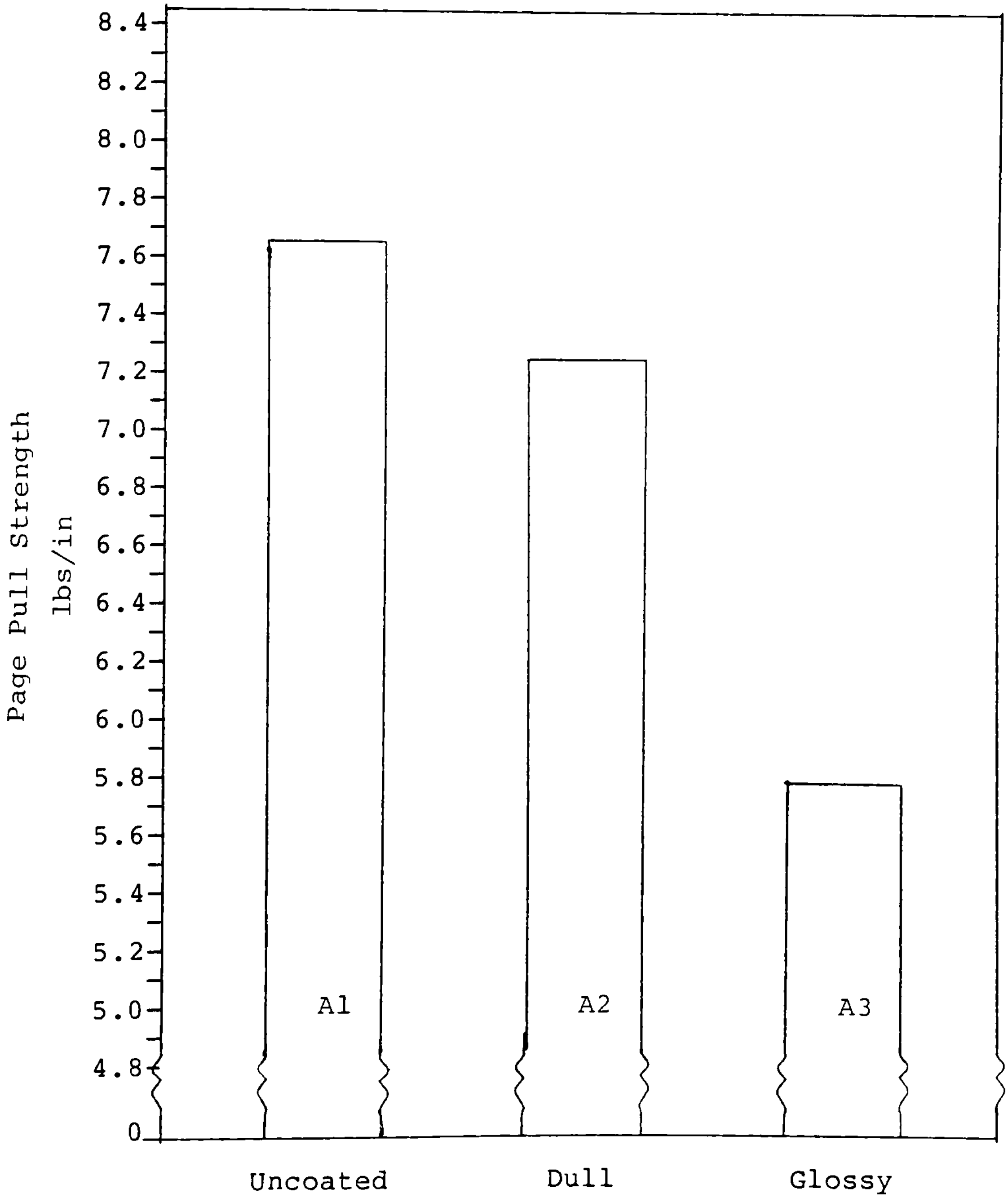
To take a closer look at the effect of paper on binding strength, all scores of the 18 books with uncoated paperstock were averaged (across all conditions and binding methods). The same was done for the 18 dull and 18 glossy volumes. These three averages were plotted on a graph shown in Figure 16, Paper Main Effect. The uncoated stock overall yielded the best binding strength (7.65 lbs/in), dull second best (7.25 lbs/in), and glossy definitely the worst (5.79 lbs/in). The ANOVA proved that the paper is a significant factor. It should be noted that although the paper had a significant influence on binding strength, the scores did not reflect a ceiling or limit reached due to the inherent strength (or rather weakness) of the paper itself. The paper did not rupture or tear in the middle; each came loose at the binding edge. Thus the binding strengths were all weaker than the inherent strengths (tensile, tear, internal bond, etc.) of the papers.

Figure 17, Binding Method Main Effect, illustrates the differences between the three binding methods, proven to be a significant factor by ANOVA. These scores are averages, this time disregarding condition and paper. Double fanned proved to have the best overall binding strength (7.42 lbs/in), oversewn close behind (6.99 lbs/in), and cleat-laced the least strong (6.35 lbs/in).

The averages for each of the conditions (disregarding paper and binding method) are shown in Figure 18, Condition Main Effect. These scores are very close, with the used slightly ahead (6.95 lbs/in), aged very close (6.92 lbs/in), and new also trailing almost imperceptibly behind (6.89 lbs/in). The ANOVA proved that the condition was not a main influencing factor on binding strength.

FIGURE 16

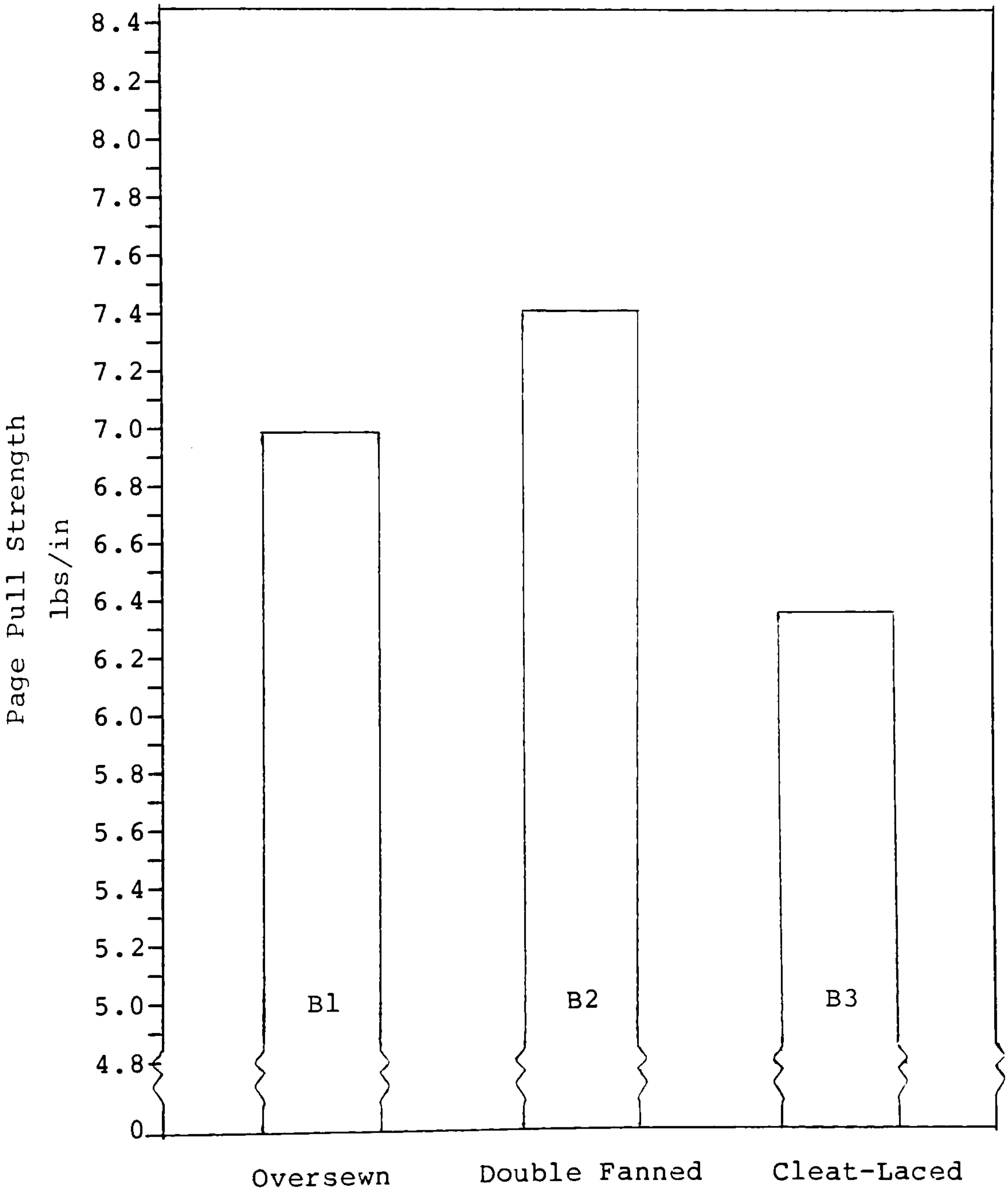
PAPER MAIN EFFECT



Scores listed in Appendix C, Table 11

FIGURE 17

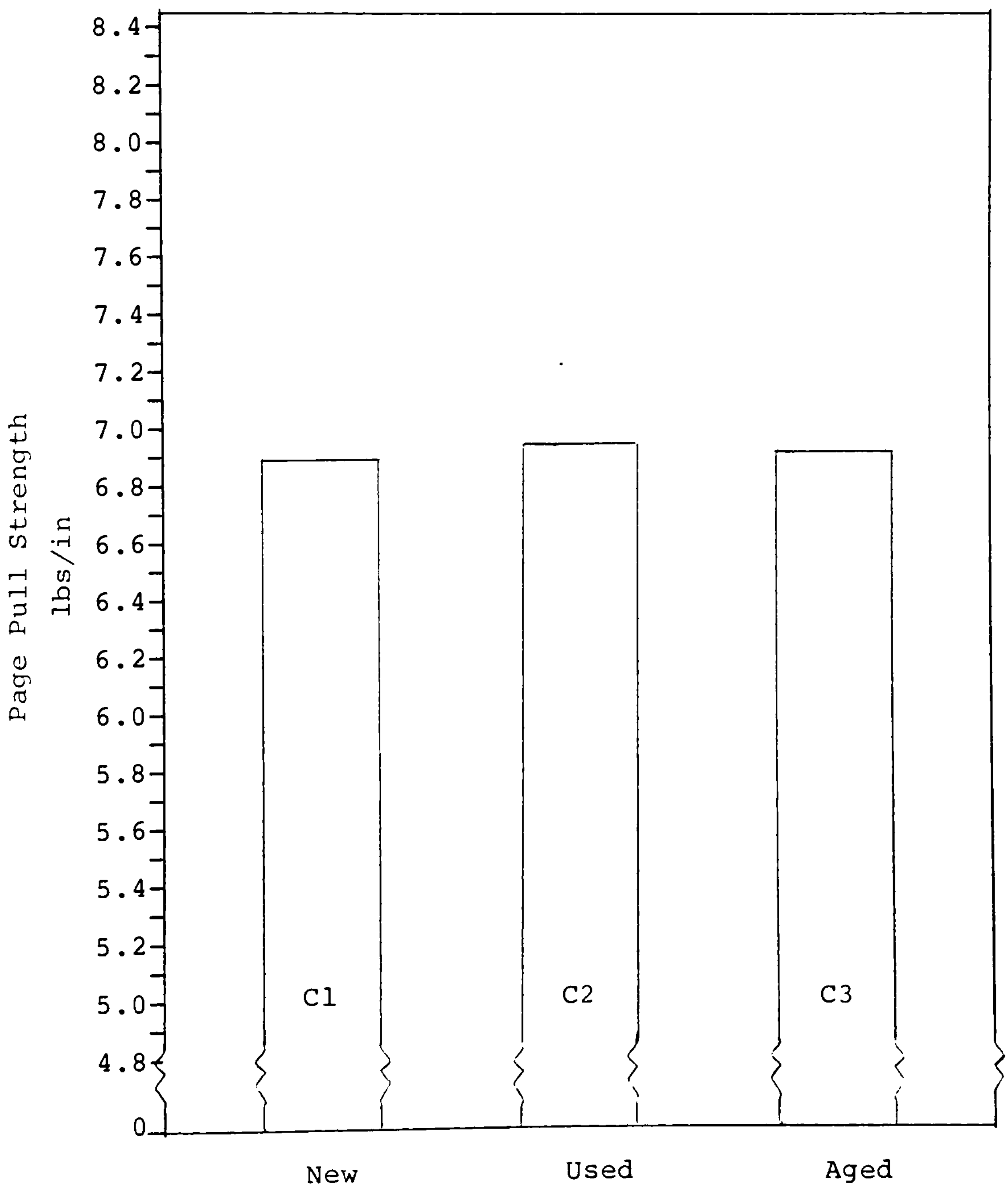
BINDING METHOD MAIN EFFECT



Scores listed in Appendix C, Table 11

FIGURE 18

CONDITION MAIN EFFECT



Scores listed in Appendix C, Table 11

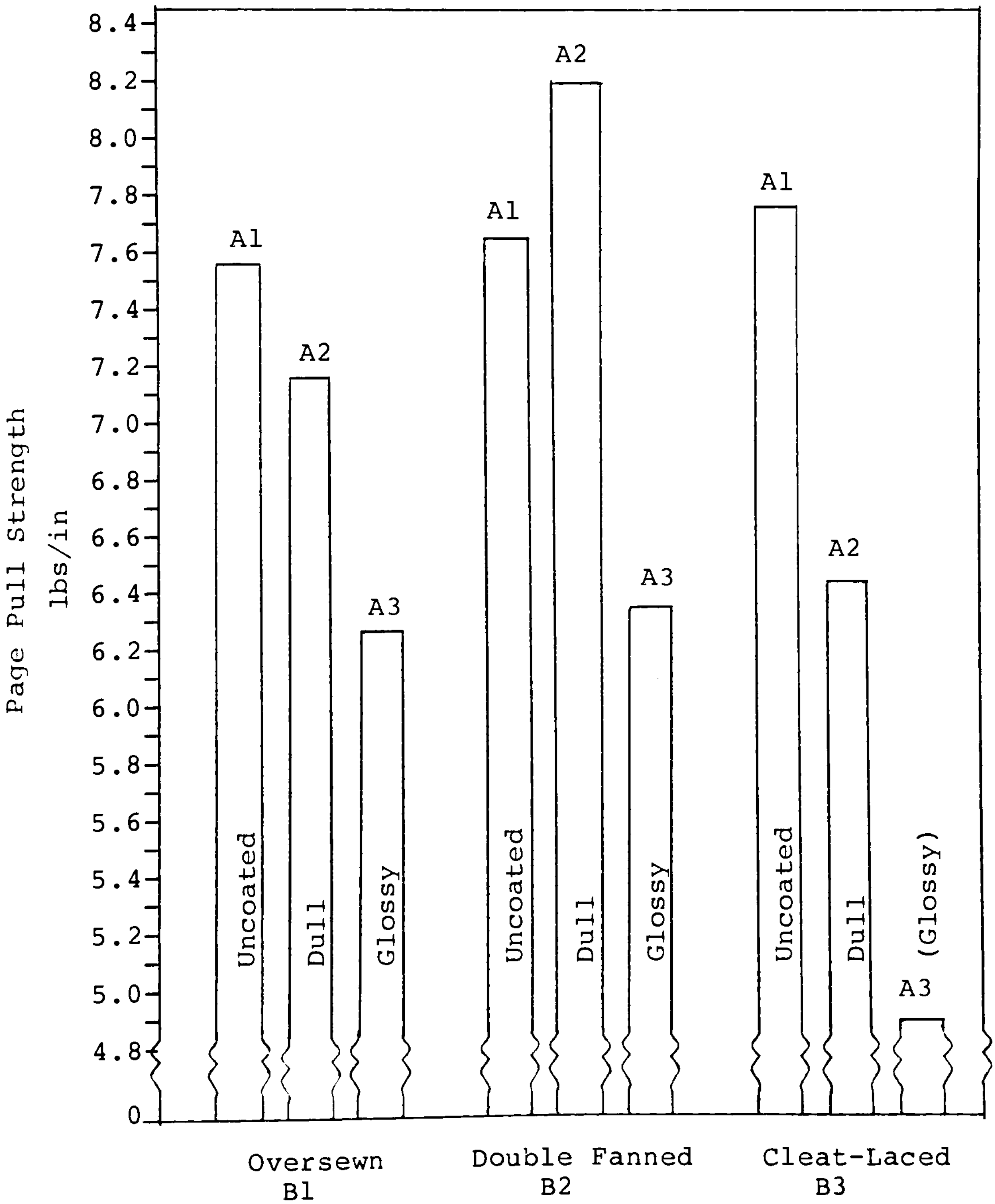
The above analysis is included to show that overall the condition has very little influence on the strength of binding in comparison with effects produced by choice of paper or binding method. The results thus far, the main effects, might lead one to conclude that the best binding strength could be obtained from a double fanned volume with uncoated stock no matter what treatment (condition) the volume received. Without studying the interactions described and evaluated in the next sections, this would be a safe bet. However, as it turns out, the best binding strength was obtained from the double fanned, used volumes with dull paperstock (8.5 lbs/in) because of the interactions. This score is 0.5 lbs/in higher than any of the double fanned, uncoated scores which was the initial guess. And surprisingly, the second highest score of all combinations was obtained with the new cleat-laced volumes with uncoated paperstock (8.19 lbs/in). As will be shown, interaction graphs have become the Optimum Binding Method Index.

Two-Way Interactions

Three sets of graphs were drawn to show the three two-way interactions. First, Figure 19A and 19B show the paper/binding method interactions (within each group, all conditions are averaged or "disregarded") yielding nine

FIGURE 19A

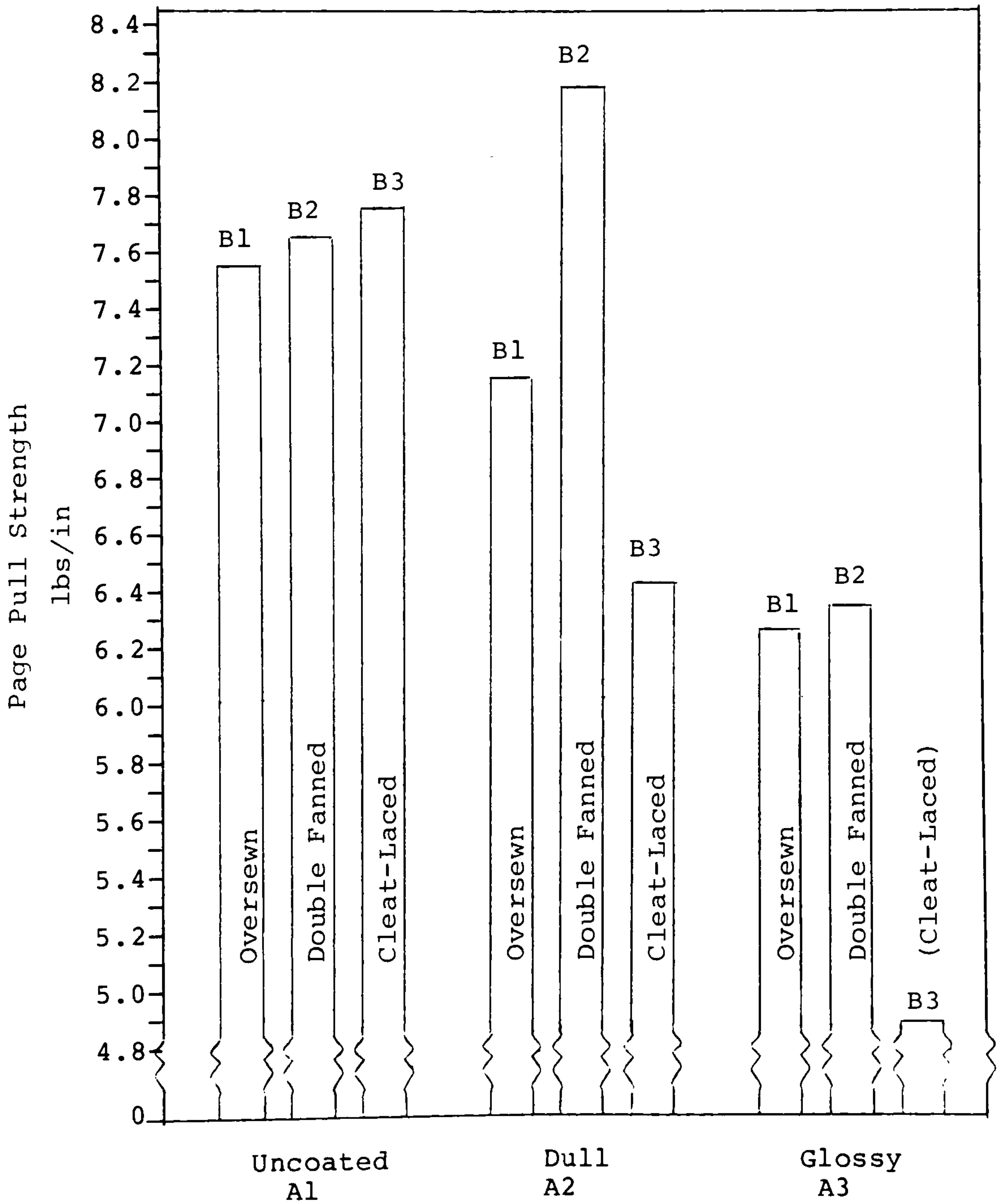
PAPER/BINDING METHOD INTERACTION, A at B



Scores listed in Appendix C, Table 12

FIGURE 19B

PAPER/BINDING METHOD INTERACTION, B at A



Scores listed in Appendix C, Table 12

different interaction influences on binding strength. Both are graphs of the same nine scores but shown from two different perspectives. Figure 19A is paper at each level of binding method (A at B) and Figure 19B is binding method at each level of paper (B at A).

Second, Figures 20A and 20B illustrate the paper/condition interactions ("disregarding" binding method). Figure 20A shows paper at each of the three condition levels, (A at C). Figure 20B represents the same nine scores but with condition at each level of paper (C at A).

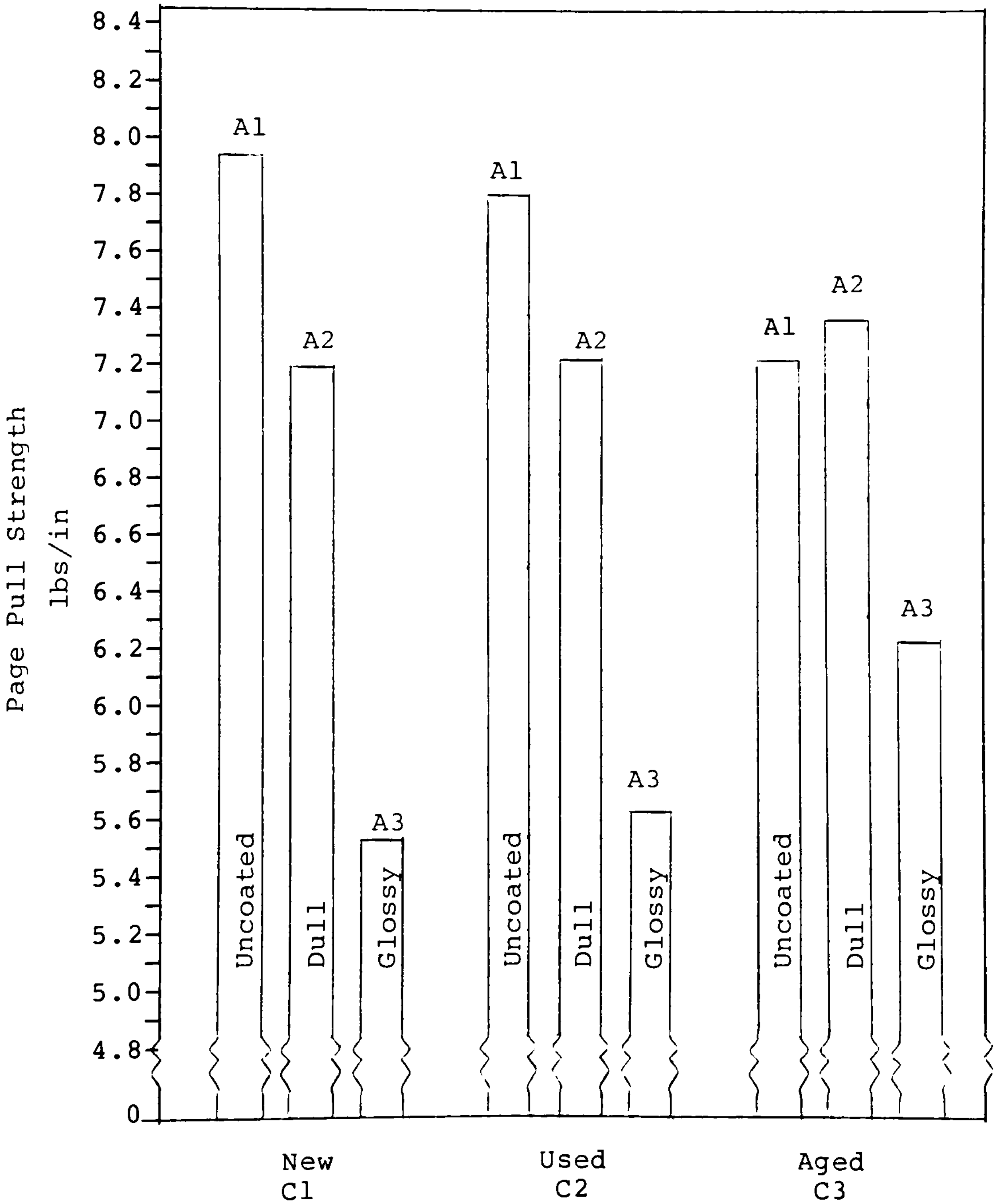
The third interaction effect, binding method/condition, is depicted in Figures 21A and 21B. Figure 21A is binding method at each level of condition (B at C) and conversely Figure 21B is condition at each level of binding method (C at B). All scores for these six graphs are in lbs/in.

Paper/Binding Method Interaction

The most noticable result, Figure 19A, of the paper/binding method interactions is that within each of the three binding methods, all three papers cause significantly different results. The ANOVA could have shown paper/binding method interaction to be significant if only one of the combinations was significantly different than the other eight. The interactions cause the order of most to least desirable paper for binding strength to change depending on

FIGURE 20A

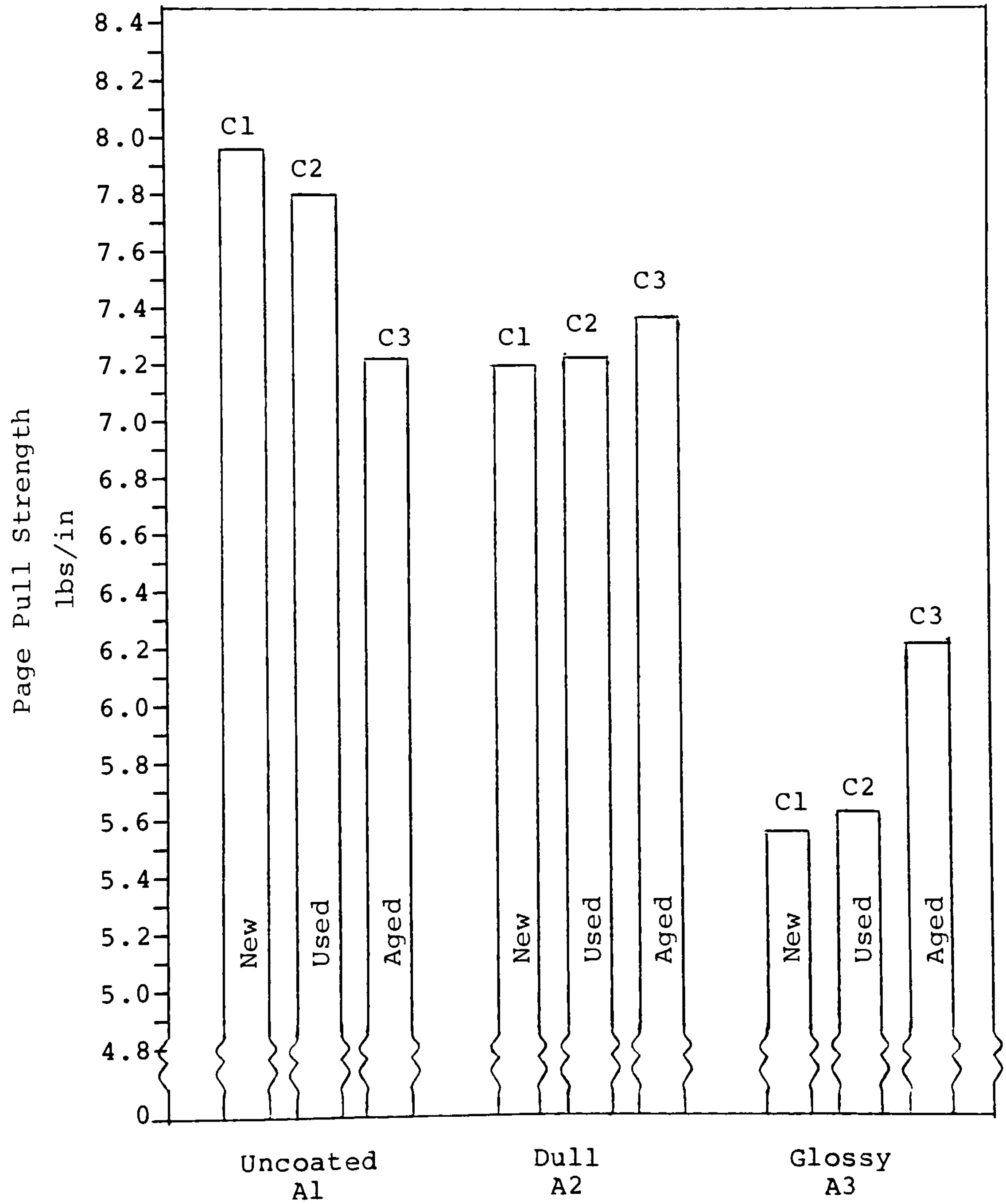
PAPER/CONDITION INTERACTION, A at C



Scores listed in Appendix C, Table 12

FIGURE 20B

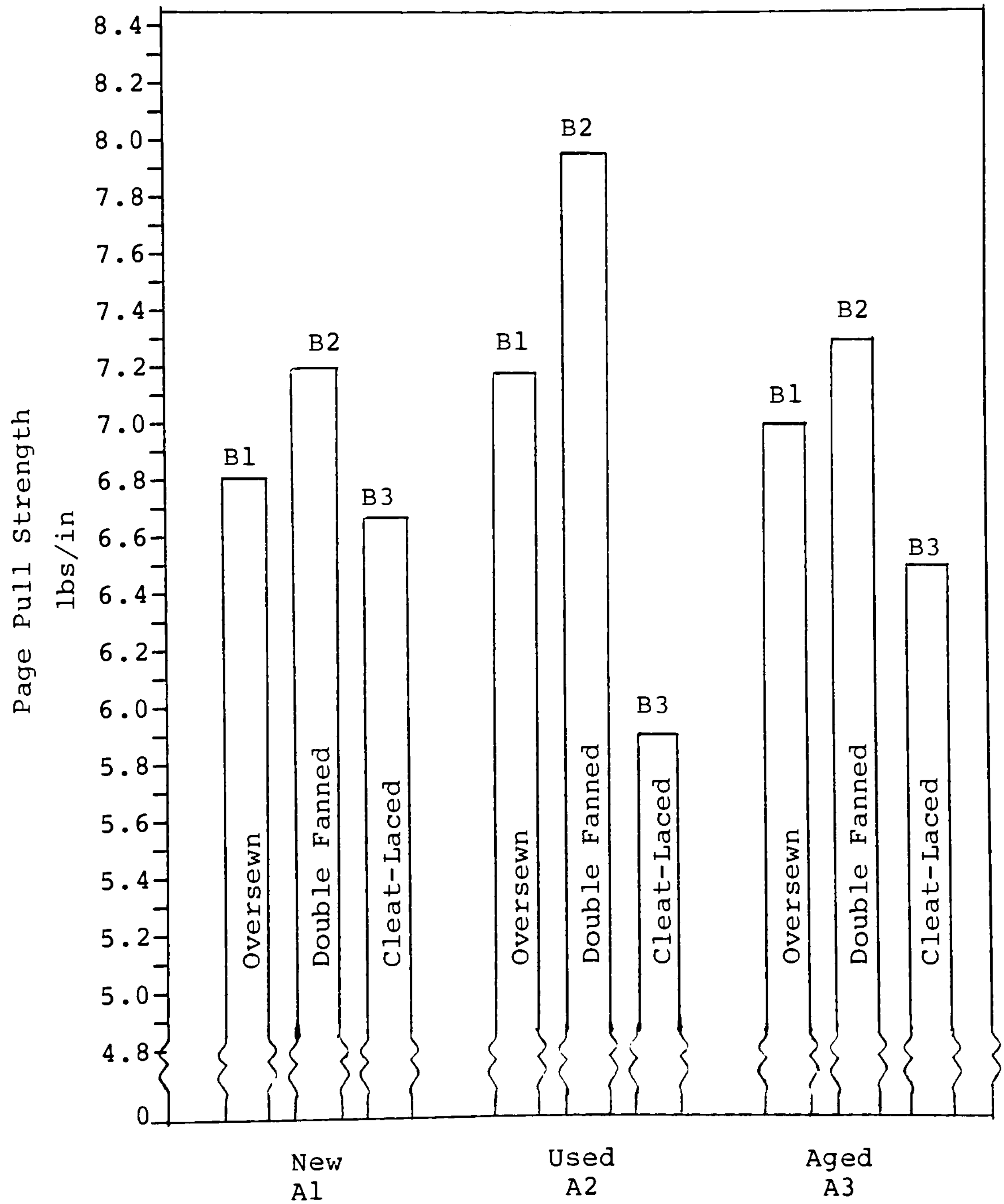
PAPER/CONDITION INTERACTION, C at A



Scores listed in Appendix C, Table 12

FIGURE 21A

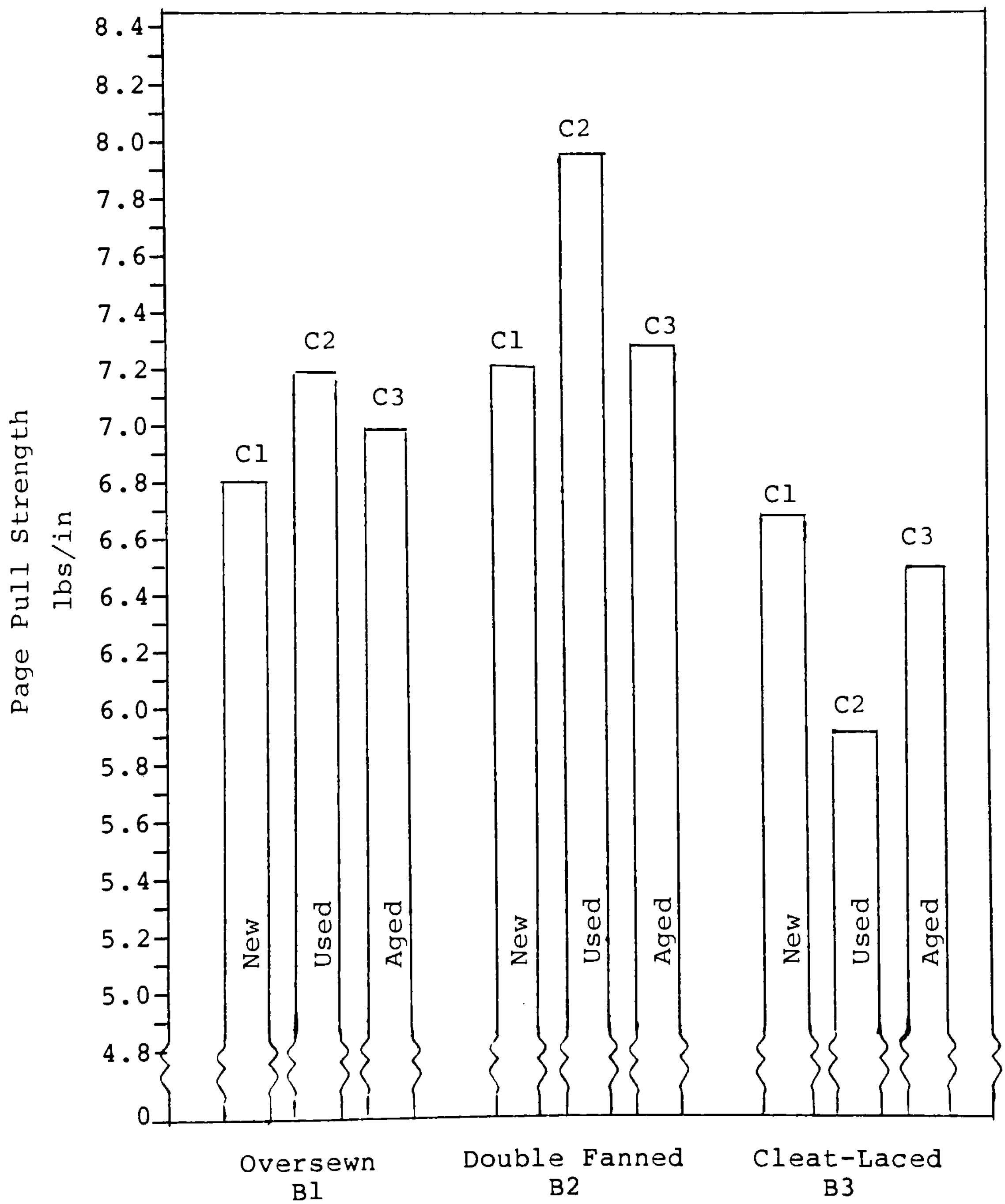
BINDING METHOD/CONDITION INTERACTION, B at C



Scores listed in Appendix C, Table 12

FIGURE 21B

BINDING METHOD/CONDITION INTERACTION, C at B



Scores listed in Appendix C, Table 12

the binding method. For oversewn, uncoated is the best paperstock, dull second, and glossy third (B1: A1 > A2 > A3). But the double fanned with dull paper exceeds the double fanned with uncoated, and the glossy double fanned is the least strong (B2: A2 > A1 > A3). The cleat-laced volumes did best with uncoated, dull second, and glossy third (B3: A1 > A2 > A3).

The total range of binding strength for these nine binding method/paper combinations is 3.32 lbs/in (4.87 to 8.19). The range of scores for the three <u>oversewn</u>/paper interactions is 1.29 lbs/in (6.26 to 7.55). The range of scores for the <u>double fanned</u>/paper interactions is 1.86 lbs/in (6.33 to 8.19). And the range of scores for the <u>cleat-laced</u>/paper interactions is a large 2.89 lbs/in (4.87 to 7.76). Thus, oversewn is the most stable or consistent binding method for strength even though it interacts with the paper. Cleat-laced is the least consistent and interaction with the glossy paperstock gives the lowest resistance to page pulling of all the combinations.

The graph in Figure 19B shows the same results from a different angle. It is most necessary at times, especially for library binders, to question what is the best binding method for the paper, rather than what the best paper is for the binding method. The <u>uncoated</u>/binding method interactions yield relatively no variability in binding strength for all three binding methods; all scores are approximately 7.7 lbs/in (A1: B1 $\simeq$ B2 $\simeq$ B3). For dull paper the best interaction is with double fanned, and the least favorable is cleat-laced (A2: B2 > B1 > B3). The glossy paper proves to be about equal for double fanned and oversewn but the cleat-laced would be the poorest choice (A3: B1 $\simeq$ B2 > B3).

The next two sections explain the paper and binding method interactions with condition. Although paper and binding method are the most important considerations when deciding on methods and materials for binding a book, condition could become important, especially when two choices are equal. Say, for example, a set of books with narrow inner margins and uncoated stock needs rebinding. The narrow inner margins rule out oversewing as a possibility. Disregarding condition, the double fanned and cleat-laced would be relatively equal in binding strength, both having approximately 7.7 lbs/in strength. The final decision may be made by looking at the binding/condition interactions as is described a little further on.

Paper/Condition Interactions

From the graph in Figure 20A, the basic relationships of the main factor, paper, can be seen. The glossy paper definitely yields the weakest binding strength, uncoated the best, and dull not far behind the uncoated.

(C1: A1 > A2 > A3, C2: A1 >A2 > A3, C3: A1 > A2 > A3). But here we are most interested in what the two conditions, use and aging, did to the binding strengths. This is best seen in Figure 20B. UBT and heat-aging tended to lower the scores for books with uncoated paperstock. Aging may tend to give books a better binding strength than when they are new if dull paper is used. But the UBT (use) appears to have no affect on books with the dull paper. The glossy paper volumes tend to have increased in binding strength after aging. The largest change in score due to treatment (condition) is found with glossy paper due to aging, where the range is 1.01 lbs/in (6.20 to 7.21).

Binding Method/Condition Interactions

The graphs in Figures 21A and 21B both demonstrate differences in binding strength caused by binding method/ condition interactions. Here, one is most interested in determining what happened to binding strength after a volume is used or after aging: this is most easily seen in Figure 21B. While "using" improved the strength of both oversewn and double-fanned bindings, it reduced the strength of cleat-laced bindings. Aging also tended to give more strength to both oversewn and double fanned bindings while it lowered the strength of the cleat-laced volumes.

Now recall the example of two choices being equal when considering paper/binding method interactions. This was the situation where uncoated/double fanned appeared equal to the uncoated/cleat-laced. The binding method/ condition interaction shows the double fanned would be the better choice as use and aging tend to give more strength to the double fanned and the same conditions tend to weaken the cleat-laced binding strengths. This is not to say cleat-laced had a poor performance, just that double fanned was slightly better.

The binding method/paper interaction had more influence on binding strength than either paper/condition or binding method/condition interactions. This was expected as condition did not have a main effect as did paper and binding method. The exact strength scores, standard deviations, and average scores are contained in Appendix B, Tables 7-12.

In summary, ANOVA has shown there is a mathematical model defining binding strength which is slightly different than the hypothesized one. This new model was derived by rejecting or failing to reject the null hypotheses for each of the factors or interactions as follows:

1. H_o: A_i=0. Reject.

   Conclude that the paper significantly influences the binding strength.

2. H_o: B_j=0. Reject.

   Conclude that the binding method factor significantly influences the strength of a binding.

3. H_o: $C_j=0$. Fail to Reject.

   Conclude that these particular conditions failed to have a significant effect on binding strength.

4. H_o: $(A \times B)_{ij}=0$. Reject.

   Conclude that paper/binding method interaction significantly influences binding strength.

5. H_o: $(A \times C)_{ik}=0$. Reject.

   Conclude that paper/condition interaction significantly influences binding strength.

6. H_o: $(B \times C)_{jk}=0$. Reject.

   Conclude that the binding method/condition interaction significantly influences binding strength.

7. H_o: $(A \times B \times C)_{ijk}=0$. Fail to Reject.

   Conclude that paper/binding method/condition interaction failed to have a significant influence on binding strength.

The mathematical model now becomes:

$$x_{ijkl} = u + A_i + B_j + (A \times B)_{ij} + (A \times C)_{ik} + (B \times C)_{jk} + E_{l(ijk)}$$

The terms C_j and $(A \times B \times C)_{ijk}$, condition and multiple interaction, are omitted because the tests failed to reject these null hypotheses. This conclusion is not about all possible binding methods, all possible conditions, all possible paperstocks, or all testing methods. However, it is a definite conclusion about the particular books and tests designed for this study, the beginnings of an Optimum Binding Method Index.

FOOTNOTE FOR CHAPTER 5

[1]Werner Rebsamen, "Performance Comparison of Oversewn, Double Fanned and Cleat-Laced Bindings," The Library Scene (March 1978), p. 21.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study, strength and openability performance comparisons of oversewn, PVA double fanned, and cleat-laced bindings, has accomplished its main objective: it introduces an Optimum Binding Method Index for library books with Class A, LBI Standard, specifications (except method of binding). The Optimum Binding Method Index is presented in the form of graphs and data tables. They give precise, comparative information about books with specified dimensions, taking the factors of paper and condition into consideration. The analysis of variance (ANOVA) shows which binding strength differences are significant and to which factors the differences are due.

The Openability Photocopy Test--inspired by the demands modern copying machines place on a book's openability (which exceed the demands for readability)--proved to be a simple, accurate testing method. There were definite openability differences among the three binding methods compared in each of the three paper categories. The largest range between binding methods of the same paper and condition was equal to 1-5/16 inch. (All books were bound with paper grain parallel to the binding edge.) The double fanned binding method's openability was superior to both oversewn and cleat-laced across all three papers. The glossy double fanned books exceeded all other openability scores. For double fanned books of greater weight than the test books, glossy paper would be unsuitable: a book opened totally flat cannot have wear resistance because of excessive stress on glued edges. Larger PVA double fanned books have been known to split at the binding edge. The cleat-laced volumes' openability was not as great as double fanned but quite consistent across all papers. Oversewn, with scores slightly less than cleat-laced, also proved to have a uniform clamping effect and therefore not much variability across all three papers. The effect of use (UBT) shows a trend of slightly increasing openability. This was expected as bindings are "loosened" and thus more flexible after use. Aging tends to decrease openability which could be expected from embrittlement or flexibility loss in papers and adhesives. The graphs in Figures 12 through 15 illustrate these results and are the Optimum Binding Method Index for openability.

Both the PVA double fanning and cleat-lacing binding methods, used in conjunction with Class A specifications, have the capacity to give a book superior internal strength and durability to that offered initially by an edition binder. Thus, the aim of the library binding industry of prolonging the useful life of a volume can be accomplished with these two alternate binding methods. This main conclusion is drawn from the Martini page pull strength test results. These internal strength tests revealed that all three binding methods exceed LBI's score of 4.0 lbs/in for a rating of "Excellent." This held true for all papers tested (uncoated, dull, glossy; 60 lbs) and all conditions tested (new, used, aged).

There were definite binding strength differences (statistically significant) among the binding method, paper, and condition combinations above this score of 4.0 lbs/in. These varied from the lowest score of 4.26 to the highest score of 8.50. This variability was due, in part, to the two main factors of 1) paper and 2) binding method. Paper had the larger significant influence of the two. Condition (new, used, aged) had no significant influence on strength by itself. All three two-way interactions (paper/condition, paper/binding method, binding method/condition) caused significant differences in binding strengths. The paper/binding method interaction had the greatest two-way effect. The three-way multiple interaction (paper/binding method/condition) had no significant influence on binding strength.

In general, the binding method main factor resulted in binding strengths as follows, in order of decreasing strength: 1) PVA double fanned, 2) oversewn, 3) cleat-laced. Oversewn was the most consistent across all papers and conditions. In general, the paper main factor resulted in binding strengths as follows, in order of decreasing strength: 1) uncoated, 2) dull, and 3) glossy. Uncoated paper yielded the most consistent strengths across all binding methods and all conditions. Glossy paper resulted in the lowest binding strengths. These results are graphed in Figures 16 through 18, and are the first part of the Optimum Binding Method Index for strength.

The above general conclusions about binding strengths (main factors) do not always hold true for particular combinations and therefore graphs in Figures 19A through 21B are included as the second (and last) part of the Optimum Binding Method Index for strength. These depict the three two-way interactions (condition included) which cause significant variability in binding strengths. Cleat-laced in combination with uncoated paper did equally well as either oversewn or double fanned. Therefore, cleat-lacing would be suitable for textbooks of this size. However, the interaction of cleat-laced with glossy paper yielded the lowest paper/binding method strength scores. These six graphs should be used for decision making in library binding. The influence of paper and the two-way interactions on binding strength show why one binding method does not <u>always</u> yield the optimum binding for a particular set of circumstances.

In conclusion, librarians and library binders may now make more informed decisions in selecting a proper alternate binding method for a library book, cleat-lacing or double fanning, taking into consideration paper, condition, and the end use or requirements of that particular book. These experiments led to optimum choices under the specific set of parameters designed for this study. Further research is needed for books with different dimensions and qualities, such as paper grain perpendicular to the binding edge, so the mistake of yielding to the temptation of making inferences about other book types is avoided. It was the intention of this study, in its detail, for researchers to follow suit by building on this groundwork. All data gathered in a similar manner can be directly compared to the standard units of measurement used in this study.

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APPENDICES

APPENDIX A

TABLE 1

BOOK TREATMENT WITH IDENTIFICATION BY CODING

TABLE 1

BOOK TREATMENT WITH IDENTIFICATION BY CODING

		PAPER (A)						
		Uncoated A1		Dull A2		Glossy A3		
BINDING METHOD (B)	Oversewn B1	$C1^a$	$C1^b$	$C1^a$	$C1^b$	$C1^a$	$C1^b$	C1 New
		$C2^a$	$C2^b$	$C2^a$	$C2^b$	$C2^a$	$C2^b$	C2 Used
		$C3^a$	$C3^b$	$C3^a$	$C3^b$	$C3^a$	$C3^b$	C3 Aged
	Double Fanned B2	$C1^a$	$C1^b$	$C1^a$	$C1^b$	$C1^a$	$C1^b$	C1 New
		$C2^a$	$C2^b$	$C2^a$	$C2^b$	$C2^a$	$C2^b$	C2 Used
		$C3^a$	$C3^b$	$C3^a$	$C3^b$	$C3^a$	$C3^b$	C3 Aged
	Cleat-Laced B3	$C1^a$	$C1^b$	$C1^a$	$C1^b$	$C1^a$	$C1^b$	C1 New
		$C2^a$	$C2^b$	$C2^a$	$C2^b$	$C2^a$	$C2^b$	C2 Used
		$C3^a$	$C3^b$	$C3^a$	$C3^b$	$C3^a$	$C3^b$	C3 Aged
								CONDITION (C)

54 total books

Uncoated = Warren's Old Style Offset, 60 lb
Dull = Warren's Patina Matte, 60 lb
Glossy = Warren's Casco Gloss, 60 lb

Exponents "a" and "b" identify replicates. Example: $A3B2C3^a$ identifies one of the two glossy paper, double fanned, aged volumes. Its replicate is $A3B2C3^b$.

APPENDIX B

TABLES 2-6

OPENABILITY TEST SCORES

TABLE 2
OPENABILITY PHOTOCOPY TEST RESULTS
Raw Scores (inches)

		Uncoated A1			Dull A2			Glossy A3		
Oversewn	B1	C1	2-17/32	2-15/32	C1	2-19/32	2- 7/32	C1	2- 8/32	2-10/32
		C2	2-16/32	2-19/32	C2	2-20/32	2-17/32	C2	2-21/32	2-21/32
		C3	2-17/32	2-16/32	C3	2- 4/32	2-12/32	C3	2- 8/32	2- 4/32
Double Fanned	B2	C1	2-29/32	2-25/32	C1	3- 6/32	3- 4/32	C1	3-12/32	3-16/32
		C2	3- 6/32	3- 3/32	C2	*	3-10/32	C2	3-19/32	3-19/32
		C3	2-28/32	2-23/32	C3	3- 2/32	3- 2/32	C3	3-15/32	3-16/32
Cleat-Laced	B3	C1	2-25/32	2-23/32	C1	2-22/32	2-29/32	C1	2-23/32	2-20/32
		C2	3- 2/32	2-30/32	C2	2-22/32	2-28/32	C2	3- 6/32	2-27/32
		C3	2-19/32	2-22/32	C3	2-17/32	2-23/32	C3	2-23/32	2-24/32

* Score discarded. C = Condition: C1 = New, C2 = Used, C3 = Aged

TABLE 3

SCORES OF OVERALL OPENABILITY RESULTS

Overall Averaged Scores of Each Binding Method
With Each Paper
(inches)

		Uncoated A1	Dull A2	Glossy A3
Oversewn	B1	Actual 2-16.5/32 Coded 10.5	Actual 2-13/32 Coded 7.0	Actual 2-12/32 Coded 6.0
Double Fanned	B2	Actual 2-29.5/32 Coded 23.5	Actual 3-5/32 Coded 31.0	Actual 3-11/32 Coded 42.0
Cleat-Laced	B3	Actual 2-25.5/32 Coded 19.5	Actual 2-23.5/32 Coded 17.5	Actual 2-26/32 Coded 20.0

Each score represents an average of 6 raw scores ($C1^a$, $C1^b$, $C2^a$, $C2^b$, $C3^a$, $C3^b$) of each paper/binding method except the $A2B2C2^a$ score was discarded.

Coded scores are computed by subtracting 2-6/32" from the actual score (Example: 2-13/32" minus 2-6/32" is equal to 7/32", coded score is 7).

Figure 12 is a graph of Table 3 coded scores.

TABLE 4

OPENABILITY SCORES OF NEW BOOKS

Average Scores of Replicate Books

(inches)

		Uncoated A1	Dull A2	Glossy A3
Oversewn	B1	Actual 2-16/32 Coded 10.0	Actual 2-13/32 Coded 7.0	Actual 2- 9/32 Coded 3.0
Double Fanned	B2	Actual 2-27/32 Coded 21.0	Actual 3-5/32 Coded 31.0	Actual 3-14/32 Coded 40.0
Cleat-Laced	B3	Actual 2-24/32 Coded 18.0	Actual 2-25.5/32 Coded 19.5	Actual 2-21.5/32 Coded 15.5

Coded scores are computed by subtracting 2-6/32" from the actual score (Example: 2-13/32" minus 2-6/32" is equal to 7/32", coded score is 7).

Figure 13 is a graph of Table 4 coded scores.

TABLE 5

OPENABILITY SCORES OF USED (UBT) BOOKS

Average Scores of Replicate Books

(inches)

	Uncoated A1	Dull A2	Glossy A3
Oversewn B1	Actual 2-17/32 Coded 11.5	Actual 2-18.5/32 Coded 12.5	Actual 2-21/32 Coded 15.0
Double Fanned B2	Actual 3-4.5/32 Coded 30.5	Actual 3-10/32* Coded 36.0	Actual 3-19/32 Coded 45.0
Cleat-Laced B3	Actual 3 Coded 26.0	Actual 2-25/32 Coded 19.0	Actual 2-27/32 Coded 26.5

Coded scores are computed by subtracting 2-6/32" from the actual score (Example: 2-13/32" minus 2-6/32" is equal to 7/32", coded score is 7).

*One score discarded.

Figure 14 is a graph of Table 5 (and Table 4) coded scores.

TABLE 6

OPENABILITY SCORES OF AGED BOOKS

Average Scores of Replicate Books

(inches)

		Uncoated A1	Dull A2	Glossy A3
Oversewn	B1	Actual 2-16.5/32 Coded 10.5	Actual 2-8/32 Coded 2.0	Actual 2-6/32 Coded 0.0
Double Fanned	B2	Actual 2-25.5/32 Coded 19.5	Actual 3-2/32 Coded 28.0	Actual 3-15.5/32 Coded 42.0
Cleat-Laced	B3	Actual 2-20.5/32 Coded 14.5	Actual 2-20/32 Coded 14.0	Actual 2-23.5/32 Coded 17.5

Coded scores are computed by subtracting 2-6/32" from the actual score (Example: 2-13/32" minus 2-6/32" is equal to 7/32", coded score is 7).

Figure 15 is a graph of Table 6 (and Table 4) coded scores.

APPENDIX C

TABLES 7-12

PAGE PULL STRENGTH TEST SCORES

TABLE 7

MARTINI TESTER PAGE PULL RAW SCORES

Force Required to Pull a Single Page From Its Binding
In Kilopounds (kp), Seven Pages Per Volume

VOLUMES	SCORES						
	1	2	3	4	5	6	7
A1 B1 C1 a	30.4	26.0	35.6	29.9	32.1	33.8	30.4
A1 B1 C1 b	34.1	35.2	25.9	27.0	33.9	30.0	33.6
A1 B1 C2 a	32.8	34.0	39.6	35.1	31.7	31.1	31.4
A1 B1 C2 b	29.6	23.8	26.9	31.9	26.9	31.0	35.1
A1 B1 C3 a	34.8	30.1	35.4	28.5	27.4	29.0	29.8
A1 B1 C3 b	33.8	30.5	28.9	30.7	29.0	27.1	21.4
A1 B2 C1 a	24.9	39.6	38.7	22.1	39.6	34.6	39.6
A1 B2 C1 b	39.6	39.6	28.9	39.6	22.4	20.8	25.9
A1 B2 C2 a	31.2	35.9	39.6	39.6	30.4	33.8	34.0
A1 B2 C2 b	33.6	36.8	39.6	24.6	30.4	23.4	20.2
A1 B2 C3 a	23.6	29.0	38.6	28.6	29.3	24.1	20.2
A1 B2 C3 b	27.1	33.3	34.0	20.8	31.5	29.7	32.4
A1 B3 C1 a	23.8	33.6	27.9	37.4	37.9	38.5	37.6
A1 B3 C1 b	25.0	30.6	34.1	36.2	35.9	34.9	34.6
A1 B3 C2 a	29.8	23.2	33.4	34.9	31.6	31.6	28.2
A1 B3 C2 b	35.3	35.4	39.6	32.0	26.8	29.7	32.3
A1 B3 C3 a	31.3	33.2	35.0	32.2	26.4	28.5	32.3
A1 B3 C3 b	27.7	19.6	29.6	26.1	34.5	26.5	35.6

TABLE 7 (Continued)

Force Required to Pull a Single Page From Its Binding
In Kilopounds (kp), Seven Pages Per Volume

VOLUMES	SCORES						
	1	2	3	4	5	6	7
A2 B1 C1 a	25.2	21.5	28.2	27.3	28.4	28.4	26.3
A2 B1 C1 b	26.3	39.6	30.2	24.9	29.7	31.1	26.9
A2 B1 C2 a	31.4	28.7	29.6	35.0	32.3	26.6	28.3
A2 B1 C2 b	35.6	25.7	27.1	31.5	32.6	34.8	29.1
A2 B1 C3 a	23.9	29.9	24.3	31.6	34.2	24.4	33.6
A2 B1 C3 b	26.6	24.8	33.2	31.1	36.1	28.3	22.7
A2 B2 C1 a	22.6	39.6	39.6	39.6	34.6	32.1	29.1
A2 B2 C1 b	32.8	39.6	27.7	39.6	39.6	24.4	27.1
A2 B2 C2 a	39.6	34.8	35.1	35.4	39.6	28.2	30.6
A2 B2 C2 b	34.6	35.5	36.6	36.3	39.6	34.8	25.1
A2 B2 C3 a	28.8	39.6	32.1	17.0	32.0	28.1	32.1
A2 B2 C3 b	33.1	39.6	39.6	39.6	36.6	34.6	17.6
A2 B3 C1 a	22.1	23.7	36.7	29.7	18.9	29.0	29.2
A2 B3 C1 b	21.6	26.0	25.3	23.6	35.1	25.6	24.1
A2 B3 C2 a	22.0	19.8	26.2	23.2	24.5	24.4	20.5
A2 B3 C2 b	20.8	19.9	23.1	22.4	29.3	24.8	21.9
A2 B3 C3 a	25.3	26.1	31.9	30.1	33.6	29.6	31.4
A2 B3 C3 b	28.6	28.1	27.8	30.5	32.5	21.8	30.1

TABLE 7 (Continued)

Force Required to Pull a Single Page From Its Binding In Kilopounds (kp), Seven Pages Per Volume

VOLUMES	SCORES						
	1	2	3	4	5	6	7
A3 B1 C1 a	24.4	25.0	25.6	26.3	24.3	21.6	20.0
A3 B1 C1 b	28.0	20.2	30.3	20.6	22.6	22.5	23.6
A3 B1 C2 a	29.2	28.2	32.6	33.4	28.2	23.6	19.9
A3 B1 C2 b	21.4	24.1	21.8	29.5	27.8	24.0	17.0
A3 B1 C3 a	29.0	25.2	30.8	30.2	30.7	29.1	31.0
A3 B1 C3 b	30.4	24.2	28.6	25.2	27.6	19.8	16.5
A3 B2 C1 a	13.3	31.1	20.3	17.1	39.6	9.6	19.0
A3 B2 C1 b	21.5	23.1	19.0	39.6	23.1	18.6	15.1
A3 B2 C2 a	29.4	27.4	39.6	39.6	29.4	17.1	15.1
*A3 B2 C2 b	17.4	13.9	29.1	18.8	39.6	9.8	6.3
A3 B2 C3 a	37.6	37.3	27.8	28.5	34.3	18.2	16.1
A3 B2 C3 b	15.6	16.1	37.7	27.2	37.9	34.0	28.0
A3 B3 C1 a	21.6	23.4	21.9	21.6	19.4	21.0	29.5
A3 B3 C1 b	19.2	21.6	21.1	19.6	23.2	17.9	22.9
A3 B3 C2 a	17.4	14.4	13.0	12.5	13.5	14.8	20.6
A3 B3 C2 b	17.5	17.1	23.2	15.7	18.6	20.5	24.5
A3 B3 C3 a	23.4	18.8	23.8	23.4	16.6	21.4	20.9
A3 B3 C3 b	21.5	20.3	21.6	18.1	20.3	18.6	19.4

* This score omitted in further computations.

TABLE 8

AVERAGE STRENGTH SCORES IN KILOPOUNDS PER NINE INCHES

		Uncoated A1	Dull A2	Glossy A3
Oversewn B1	C1	31.28	28.14	23.93
	C2	31.49	30.59	25.76
	C3	29.74	28.91	27.02
Double Fanned B2	C1	32.56	33.43	22.14
	C2	32.36	34.70	*28.23
	C3	28.73	32.17	28.31
Cleat-Laced B3	C1	33.43	26.47	21.71
	C2	31.70	23.06	17.38
	C3	29.89	29.10	20.58

C1 = New
C2 = Used
C3 = Aged

* Each score represents the mean (average) score of 14 page pulls (exception: A3B2C2[b] scores were omitted).

TABLE 9

STANDARD DEVIATIONS (s) OF STRENGTH SCORES IN TABLE 8

			Uncoated A1	Dull A2	Glossy A3
Oversewn	B1	C1	3.30	4.11	3.00
		C2	3.97	3.22	4.83
		C3	3.52	4.48	4.42
Double Fanned	B2	C1	7.88	6.34	8.94
		C2	6.16	4.21	9.65
		C3	5.22	7.43	8.68
Cleat-Laced	B3	C1	4.80	5.02	2.76
		C2	4.10	2.64	3.75
		C3	4.43	3.15	2.14

C1 = New
C2 = Used
C3 = Aged

TABLE 10

AVERAGE STRENGTH SCORES IN POUNDS PER INCH

		Uncoated A1	Dull A2	Glossy A3
Oversewn B1	C1	7.66	6.89	5.86
	C2	7.71	7.49	6.31
	C3	7.29	7.08	6.62
Double Fanned B2	C1	7.98	8.19	5.42
	C2	7.93	8.50	*6.91
	C3	7.04	7.88	6.93
Cleat-Laced B3	C1	8.19	6.48	5.32
	C2	7.77	5.65	4.26
	C3	7.32	7.13	5.04

C1 = New
C2 = Used
C3 = Aged

* Each score represents the mean (average) score of 14 page pulls (exception: A3B2C2[b] scores were omitted).

TABLE 11

AVERAGE STRENGTH SCORES OF MAIN FACTORS

PAPER		
	kp/9 in	lbs/in
A1 Uncoated	31.24	7.65
A2 Dull	29.62	7.25
A3 Glossy	23.64	5.79

BINDING METHOD		
	kp/9 in	lbs/in
B1 Oversewn	28.54	6.99
B2 Double Fanned	30.41	7.42
B3 Cleat-Laced	25.92	6.35

CONDITION		
	kp/9 in	lbs/in
C1 New	28.12	6.89
C2 Used	28.37	6.95
C3 Aged	28.27	6.92

Figures 16, 17, and 18 are graphs of Table 11 in lbs/in

TABLE 12

AVERAGE SCORES: AB, AC, BC INTERACTIONS

PAPER/BINDING METHOD

AB	B1	B2	B3
A1	30.84 7.55	31.22 7.65	31.67 7.76
A2	29.21 7.15	33.43 8.19	26.21 6.42
A3	25.57 6.26	25.83 6.33	19.89 4.87

PAPER/CONDITION

AC	C1	C2	C3
A1	32.42 7.94	31.85 7.80	29.45 7.21
A2	29.35 7.19	29.45 7.21	30.06 7.36
A3	22.59 5.53	22.90 5.61	25.30 6.20

BINDING METHOD/CONDITION

BC	C1	C2	C3
B1	27.78 6.80	29.28 7.17	28.56 6.99
B2	29.38 7.19	32.47 7.95	29.74 7.28
B3	27.20 6.66	24.05 5.89	26.52 6.49

Upper Scores, kp/9 in; Lower Scores, lbs/in

Figures 19A, 19B, 20A, 20B, 21A, and 21B are graphs of lbs/in

APPENDIX D

TABLES 13-14

SUMMARY ANOVA AND INTERPRETATION

TABLE 13

ANOVA SUMMARY

SOURCE	SS	DF	MS	F RATIO	TABLE F RATIO
A	3620.32	2	1810.16	67.9954	$F_{2,344,0.05}=3.07$
B	1174.61	2	587.303	22.061	$F_{2,344,0.05}=3.07$
C	3.50684	2	1.75342	.065864	$F_{2,344,0.05}=3.07$
AB	890.552	4	222.638	8.36299	$F_{2,344,0.05}=2.45$
AC	358.989	4	89.7473	3.37119	$F_{4,344,0.05}=2.45$
BC	399.779	4	99.9448	3.75425	$F_{4,344,0.05}=2.45$
ABC	345.278	8	43.1598	1.62122	$F_{8,344,0.05}=2.01$
WITHIN (Error)	9157.91	344	26.6218		

TABLE 14

INTERPRETATION OF ANOVA SUMMARY

SOURCE	F RATIO		TABLE F RATIO
A	67.9954	>	3.07
B	22.061	>	3.07
C	.065864	<	3.07
AB	8.36299	>	2.45
AC	3.37119	>	2.45
BC	3.75425	>	2.45
ABC	1.62122	<	2.01

If the F Ratio is greater than (>) the Table F Ratio, then the null hypothesis is rejected for that factor (source). This means all levels of that factor are not equal and the factor does significantly affect binding strength. If the F Ratio is less than (<) the Table F Ratio, the null hypothesis is not rejected (fail to reject).

VITA

VITA

VITAL STATISTICS

U.S.A. Citizenship. Born in Greensboro, N.C., 1956.

Greensboro Public Schools; 1962-1973. National Honor Society.

HIGHER EDUCATION

Wellesley College; 1973-1974.

University of North Carolina at Greensboro. B.A. 1977, Magna Cum Laude, Phi Beta Kappa.

Rochester Institute of Technology, School of Printing, Rochester, New York; 1978-1980. Completed coursework. Presently candidate for M.S. in Printing Technology.

PROFESSIONAL EXPERIENCE

Jackson Library. University of North Carolina at Greensboro. Student Assistant, Circulation and Reserves; 1974-1977. Full Staff Member, Documents; 1977-1978.

Rochester Institute of Technology, School of Printing. Graduate Assistant, Printing Plates Course; 1979-1980.

Time Inc., Corporate Manufacturing and Distribution.

Quality Control Manager; 1980-1982.
Responsible for Discover and Money Magazines.

Corporate Operations Manager.
Responsible for HBO and HBO/Cinemax Guides; 1982-1983.

Responsible for Discover Magazine; 1983-1984.

Financial Analyst, Manufacturing and Distribution, 1984-Present.
Responsible for Discover and Life Magazines.

Have also worked on Fortune, Life, People, Sports Illustrated, and Time Magazines.